ASTM Bulletin

59th ANNUAL MEETING

Atlantic City June 18–22

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ASTM BULLETIN

FEBRUARY 1956

Number 212

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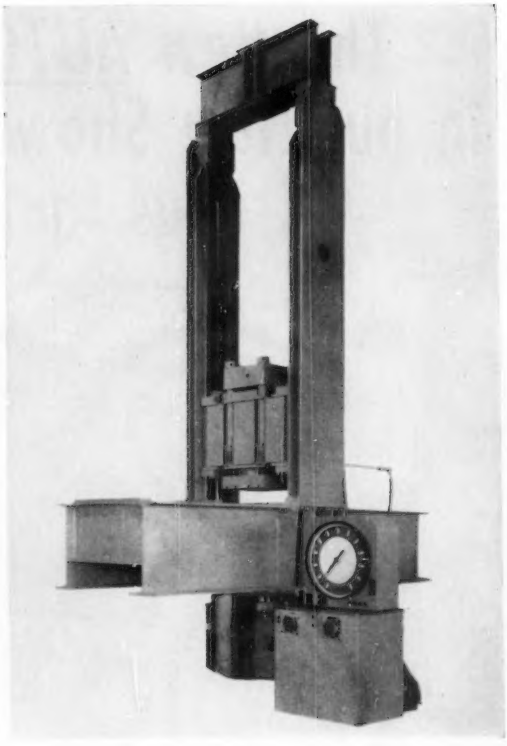

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ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

Number 212 February 1956

Annual Meeting Technical Program Takes Form

ATLANTIC CITY JUNE 18–22

THE 59th Annual Meeting, first of the two ASTM meetings that will span the continent this year—the Annual Meeting on the East Coast, the Second Pacific Area National Meeting on the West Coast—will be held in Atlantic City, N. J., June 18–22.

Chalfonte-Haddon Hall Hotel, Headquarters of the meeting, will also house the Twelfth Exhibit of Testing and Scientific Apparatus and Laboratory Supplies, and the Tenth Photographic Display and Competition.

Lecturers on Silicones and Copper

The Marburg and Gillett Lectures this year will deal with the timely subjects of silicones and copper, respectively.

Charles E. Reed, the Marburg Lecturer, is general manager of the Silicone Products Dept., General Electric Co., Waterford, N. Y.

The Gillett Lecturer, D. K. Crampton is director of research, Chase Brass and Copper Co., Waterbury, Conn.

Technical Program Shaping Up

Eight symposiums and several other sessions of grouped related papers plus the hundreds of meetings of the main technical committees and their subcommittees will provide the technical schedule of the week.

The complete advance program of the meeting will appear in the April issue of the ASTM BULLETIN. The symposium program is outlined below in as much detail as is now available.

SYMPOSIUM ON SPECIFIC GRAVITY OF BITUMINOUS COATED AGGREGATES

Sponsored by Committee D-4 on Road and Paving Materials

The Role of Specific Gravity in the Design and Control of Bituminous Paving Mixtures by C. A. Carpenter, Bureau of Public Roads.

Measurement of Bituminous Concrete Core Densities and Density of Bituminous Coated Aggregates by Means of a Volumeter by F. M. Williams, Ohio State University.

Specific Gravity of Bituminous Coated Aggregates by Solvent Immersion by Paul J. Serafin, Michigan State Highway Dept.

Effective Specific Gravity of Bituminous Coated Aggregates by J. Rogers Martin and A. H. Layman, Jr., Asphaltic Concrete Association of Oklahoma.

Measurement of Maximum Density of Bituminous Mixtures by Vacuum-Saturation Technique by James M. Rice, National Crushed Stone Assn.

Specific Gravity and Voids Relationships in Bituminous Pavement Mix Design by J. L. McRae, Waterways Experiment Station.

SYMPOSIUM ON pH MEASUREMENT

Sponsored by Committee E-1 on Methods of Testing

Introduction by E. B. Ashcraft, Westinghouse Electric Corp.

Meaning and Standardization of pH Measurement by R. G. Bates, National Bureau of Standards.

Errors of pH Measurements by G. A. Perley, Leeds & Northrup Co.

Performance Studies of pH Electrodes and Their Components at High Temperatures and Pressures by John Leonard, Beckman Instruments, Inc.

Theoretical and Practical Problems in the Measurement of Acidity in Aqueous and Nonaqueous Media by Martin Kilpatrick, Illinois Institute of Technology.

Indicator Acidity Functions for Nonaqueous and Mixed Solvents by Martin A. Paul and F. A. Long, Cornell University.

Problems in Measurements of the pH of Blood and Other Biological Fluids by Julius Sendroy, Jr., Naval Medical Research Institute.

SYMPOSIUM ON RHEOLOGY

Sponsored Jointly by the Society of Rheology and Committee E-1 on Methods of Testing

Stresses and Strains in the Shaping of Metal Tubes by E. T. Onat and W. Prager, Brown University.

Stress-Strain Relations in Soils by D. C. Drucker, Brown University.

Rheological Properties of Asphalts by W. Philippoff, Franklin Institute.

Photographic Method for Sharpening Isochromatic Photoelastic Patterns by R. R. Myers, Lehigh University.

Dynamic Viscosity and Shear Modulus of Molten Polystyrene as a Function of Molecular Weight by W. P. Cox, L. E. Nielsen, and R. Keeney, Monsanto Chemical Co.

The Impact Absorbing Capacity of Textile Yarns by J. C. Smith, F. L. McCrackin, and H. F. Schiefer, National Bureau of Standards.

The Characterization of Pressure-Sensitive Adhesives by Frank H. Wetzel, Hercules Powder Co.

SESSION ON SOILS

Sponsored by Committee D-18 on Soils for Engineering Purposes

Evaluation of Lime Stabilized Loess by J. G. Laguros and D. T. Davidson, Iowa State College.

Field and Laboratory Determinations of the Bearing Capacity of Hard Pan for Design of Deep Foundations by W. S. Housel, University of Michigan.

Applications of Environment Testing of Soils by Donald M. Burmister, Columbia University.

Research on the Ultimate Bearing Value of Pressure-Injected Footings in Lieu of Poured-in-Place Shallow Footings in Granular Materials by L. A. Fraikin, Franki Foundation Co.

SYMPOSIUM ON SOLDERS, FLUXES AND TESTING OF JOINTS

Sponsored by Committee B-2 on Non-Ferrous Metals and Alloys

An extensive program is planned which will include five papers in the area of soldering technique, three papers in the field of evaluation of solders, one paper on galvanic corrosion in joints, one paper in the area of testing methods and three papers in the general field of fluxes. More detailed information will be given in the next issue of the ASTM BULLETIN.

SYMPOSIUM ON IN-PLACE SHEAR TESTING OF SOILS BY THE VANE METHOD

Sponsored by Committee D-18 on Soils for Engineering Purposes

Vane Testing for Shear Strengths of Clays—Principles and Summary of Work to Date by J. O. Osterberg, Northwestern University.

A Practical Vane Test for in-Place Shear of Foundation Soils by Harold J. Gibbs and W. G. Holtz, Bureau of Reclamation.

Vane Device for In-Place Soil Shear Measurement by W. A. Hill, Oregon State Highways Dept.

Deep Vane Tests in Gulf of Mexico by Carl W. Fenske, McClelland Engineers.

SYMPOSIUM ON ION EXCHANGE AND CHROMATOGRAPHY IN ANALYTICAL CHEMISTRY

Sponsored by Committee E-3 on Chemical Analysis of Metals

The Use of Ion Exchange Resins in Analytical Chemistry by Robert Kunin, Rohm and Haas Co.

Ion Exchange in Analytical and Radiochemistry by J. E. Hudgens, Bettis Plant of Westinghouse Electric Corp.

Anion Exchange in Metal Separations by Kurt Kraus, Oak Ridge National Laboratory.

Ion Exchange in Metals Analysis by John L. Hague, National Bureau of Standards.

SYMPOSIUM ON TENSION TESTING OF NONMETALLIC MATERIALS

Sponsored by Committee E-1 on Methods of Testing

Tension Testing of Rubber by H. Tangenberg, B. F. Goodrich Co.

Tension Testing of Plastics by F. W. Reinhart, National Bureau of Standards.

Tensile Load-Deformation Testing of Textile Structures by Stanley Backer, Massachusetts Institute of Technology.

Tension Test Methods for Wood, Wood-Base Materials and Sandwich Constructions by L. J. Markwardt and W. G. Youngquist, Forest Products Laboratory.

Tension Testing of Adhesives by A. G. H. Dietz, Massachusetts Institute of Technology.

Present Practices in Tensile Strength Testing of Paper in Industry by John Fachet and F. T. P. Plimpton, Jr.

SYMPOSIUM ON STEAM QUALITY

Sponsored by Joint Research Committee on Boiler Feedwater

Total Dissolved Solids in Condensed Steam by Amplification and Conductivity by W. B. Gurney, Gulf States Utilities Co.

Steam Purity Determination by Tracer Techniques by Earl E. Coulter, Babcock & Wilcox Co.

Steam Quality Determination by Means of the Hagen Degasser, West Penn Power Co.

Operating Experiences with the Larsen Lane Steam Purity Analyzer by A. B. Sisson, Commonwealth Edison Co. and R. W. Lane, Illinois State Water Survey.

Twelfth Exhibit of Testing and Scientific Apparatus and Laboratory Supplies

A MOST interesting and educational part of the Annual Meeting will be the 12th Exhibit of Testing and Scientific Apparatus and Laboratory Supplies. These exhibits serve an important educational and scientific purpose by enabling our members and visitors to see at first hand many of the items useful to them in their work. items required in tentative and standard methods of test, and also items and procedures for testing materials which have not yet been adopted as standards.

The Exhibit will be held in the English Lounge and the Vernon Room at Chalfonte-Haddon Hall. Space is more than half sold and a number of exhibitors appear on the list for the first time. Companies which will exhibit include:

Ace Glass Inc.
American Cystoscope Makers, Inc.
Holger Andreasen, Inc.
Atlas Electric Devices Co.
Branson Instruments, Inc.
Buehler Ltd.
Burrell Corp.
Central Scientific Co.
Custom Scientific Instruments, Inc.
Eastman Kodak Co.
Fisher Scientific Co.
General Laboratory Supply Co.
General Radio Co.
Karl Heitz, Inc.
Instron Engineering Corp.
Laboratory Equipment Corp.
Leeds & Northrup Co.
Lindberg Engineering Co.
National Forge and Ordnance Co.
Tinius Olsen Testing Machine Co.
Research Appliance Co.
Riehle Testing Machines Division of American Machine and Metals, Inc.
Scott Testers, Inc.
Service Diamond Tool Co.
Delbert Wheeler Co., Inc.
Wilson Mechanical Instrument Division of American Chain & Cable Co., Inc.

Many more are expected to appear.

As in the past, the exhibits will be restricted to apparatus, instruments, and supplies used in testing, research, production, quality control inspection, and related work. Information about exhibiting may be obtained from ASTM Headquarters.

Photographic Exhibit

The Tenth Photographic Display and Competition will be an important part of the Exhibit and will be in an area adjacent to the Exhibit hall. The country's best technical photographers will participate. The committee for 1956 expects to surpass even the 1954 exhibit which was most noteworthy, especially for photomicrographs involving metallography and electron micrographs. Application forms for entries in the Photographic Exhibit have been mailed to all members and committee members. Any member or any interested employee of a company holding ASTM membership is eligible to enter the competition and will be sent an application form on request.

YOUR APRIL BULLETIN will carry the complete PROVISIONAL PROGRAM of the 59th Annual Meeting, June 18–22 in Atlantic City.

Latest Actions on ASTM Standards

December and January

Rubber

(Approved December 19, 1955)

Tentative Methods for Chemical Analysis of Rubber Products (D 297 - 55 T)

REVISED to add needed procedures for the determination of iron in crude rubber.

Tentative Method of Test for Indentation of Rubber by Means of a Durometer (D 676 - 55 T)

A needed refinement to improve the method was the addition of a paragraph on the number of readings and the manner of taking them. The new Section 5(*d*) reads as follows:

5 (*d*) Number of Readings.—The test specimen shall be shifted to a new position after each contact in order to avoid errors due to fatigue effects. For standard tests, a minimum of five readings shall be taken and their median recorded as the indentation measurement.

Tentative Specifications for Rubber and Synthetic Rubber Compounds for Automotive and Aeronautical Applications (ASTM D 735 - 55 T; SAE 10R)

Title shortened to "Tentative Specifications for Elastomer Compounds for Automotive Applications." In SAE specifications the word "automotive" covers both automotive and aeronautical applications and the term "elastomer" will be defined parenthetically in the revised scope, as "Natural rubber, reclaimed rubber, synthetic rubber, or rubber-like materials, alone or in combination." While it is generally understood that the values in the tables of this specification are on laboratory prepared specimens, some consumers wish to test samples prepared from finished products and the statements contained in Paragraph 5(*b*) "Physical Requirements" are considered adequate to handle this type of situation. The committee felt, however, that it would be better to bring these statements up into the Scope by rewriting Paragraph 1(*b*). This revision makes it possible to delete Paragraph 5 entirely. The following grades will be marked with an asterisk:

Table I:	R415	R510	R610	R710
	R420	R515	R615	R715
		R520	R620	R720
		R525	R625	
Table III:		SB515	SB610	SB715
			SB615	
Table IV:	SC415	SC515	SC610	SC710
	SC420	SC520	SC615	SC715
			SC620	

At the bottom of each table the following note will appear: "In order to keep to a minimum the number of grades required, it is suggested that wherever practical, those grades designated by an asterisk be used." Table V is further revised by the addition of four new grades of silicone rubber: TA507, TA606, TA706, and TA806. These grades provide the improved higher tensile compounds now on the market.

Tentative Method of Test for Resistance to Accelerated Light Aging of Rubber Compounds (D 750 - 55 T)

Section 3(*e*) has been revised to permit more flexibility in the black panel temperature of 145 ± 5 F. Such a provision is needed in certain products, such as floor mats.

Tentative Method of Test for Viscosity of Rubber and Rubber-Like Materials by the Shearing Disk Viscometer (D 927 - 53 T)

Revised to include changes in the apparatus and in the test procedure as a result of extensive investigations carried out at the National Bureau of Standards. The committee believes that these changes represent a decided improvement, especially in the synthetic rubber program in which they are widely used for control purposes.

Tentative Method of Test for Curing Characteristics of Vulcanized Mixtures During Heating by the Shearing Disk Viscometer (D 1077 - 49 T)

This revision conforms to the changes recommended in the apparatus employed in Method D 927 and also provides for better temperature measurement during the test. It is based on extensive investigations at the National Bureau of Standards.

Tentative Method of Test for Accelerated Ozone Cracking of Vulcanized Rubber (D 1149 - 51 T)

Revised to incorporate in the text of the Scope the essentials heretofore contained in a Note appended to the Scope. These statements point out certain limitations in applicability and emphasize the inadvisability of using the test for purchase specifications because of poor reproducibility among laboratories.

Tentative Specifications for Sheet Rubber Packing (D 1330 - 55 T)

Revised to include a second grade of red sheet packing which is lower in quality and presumably cheaper than the original grade. Quality of the latter is slightly increased. The lower grade is commercially acceptable for many purposes and is widely used. Some are of the opinion that such a grade is more needed than the higher grade.

Textiles

(Approved January 4, 1956)

Tentative Method of Test for Stiffness of Fabrics (D 1388 - 55 T)

The stiffness or degree of resistance to bending is an important property of a textile fabric. This method has been developed after study by a task group of several available methods using different apparatus. The Scope of the new method reads as follows:

Two methods of test are described for determining the stiffness of fabrics—the Cantilever Test and the Heart Loop Test. Both

methods are applicable to fabrics of any fiber content and are capable of giving results that are reproducible within reasonable limits, either as within or between laboratories tests. In general, they are more suitable for testing woven than for knitted fabrics.

The Cantilever Test is the preferred method because it is simpler to carry out. It is, however, not suitable for testing very limp fabrics or fabrics which have a marked tendency to curl at a cut edge or when cut specimens have a tendency to twist excessively. In these latter cases, the Heart Loop Test may often be used.

The two methods may not give the same numerical values, and may not necessarily rank fabrics in exactly the same order. Both methods, however, give excellent correlation with a subjective evaluation obtained by feeling the fabrics.

Tentative Specifications for Fire-Retardant Properties of Treated Textile Fabrics (D 626 - 41 T)

Revised to add new paragraphs as follows: 4(*c*) conditioning of test specimens for at least 16 hr at a temperature of 70 ± 2 F and a relative humidity of 65 ± 2 per cent prior to testing; 5(*d*) gas pressure to be maintained at $2\frac{1}{2} \pm \frac{1}{4}$ psi; 5(*e*) composition of synthetic gas mixture specified (known as Matheson Manufactured Gas "B").

Standard Methods of Quantitative Analysis of Textiles (D 629 - 55 T)

Revised and reverted to tentative status to incorporate new procedures for quantitative analysis of mixtures containing Dynel and analysis of mixtures of Dacron and wool.

Methods of Testing

(Approved December 19, 1955)

Tentative Recommended Practice for Characteristics of Standard Carbon Arc Accelerated Weathering Unit (E 42 – 42 T)

Title changed to "Tentative Recommended Practice for Operation of Light and Water Exposure Apparatus (Carbon-Arc Type) for Artificial Weathering Tests." Revised to bring the practice up to date, especially with respect to apparatus and to provide for use of the black panel thermometer unit for temperature measurements. This practice is limited to the method of obtaining, measuring, and controlling the various conditions and procedures of the test but does not cover the preparation of the test specimens, the test conditions best suited for the various types of materials, or the evaluation of test results. These are covered in the various ASTM methods for testing specific materials.

1956 WEST COAST NATIONAL MEETING

Los Angeles—September 16–22

—Over 35 Technical Sessions—

Outstanding technical papers—petroleum, soils, concrete, plastics, paints, railroad materials, nuclear effects

Two exhibits—Apparatus and Instruments; Technical Photography (Prize-winning prints)

—Special Luncheons with Prominent Speakers—

A lively, competent, friendly committee of your fellow members in California believe the benefits to be derived by you and your company or department will more than justify your trip. Get ready. In May complete details and a hotel return form.

DON'T MISS IT!

Buenos Dias, Senores y Senoras:

The General Committee on Arrangements for the Second Pacific Area National Meeting at Los Angeles, California (September 16 to 22, 1956) sends you greetings.

Do hula girls, pineapples, volcanoes, and cocoanut trees on a tropical beach arouse your interest? Yes— No—

Have you seen the Parks of the Giants or Bridal Veil Falls by the soft light of a full California moon? Yes— No—

Do the daily migrations of bats to and from the Carlsbad Caverns; the Cliff Dwellers of Arizona; or the Grand Canyon, excite your imagination? Or perhaps you may prefer the glittering, neon-lighted "dives of iniquity" of the Golden West? Yes— No—

If so, have you stopped to consider that all of these wonders are only a few hours travel time from the Statler Hotel Headquarters of the Second Pacific Area National Meeting of ASTM at Los Angeles (Sept. 16 to 22, 1956)?

Ed Green, the Chairman of the Information Committee, has laboriously compiled some statistics on costs, travel time, etc., relating to these extracurricular enchantments which you and the missus may like to consider as an added inducement to our Pacific Area Meeting. In other words, tell the boss that you would like to take your vacation consecutively with the Los Angeles meeting. In this manner you travel on company time to California, attend our meeting and then as an anticlimax relax on the sun-baked sands of Waikiki. How about that?

The following list is but a provocative sample and further information can be obtained by writing to Ed Green. c/o Axelson Manufacturing Co., Box 58335, Vernon Station, Los Angeles 58, Calif.

Air Time from Los Angeles

Honolulu	9½ hours
Mexico City	5 hours
Las Vegas	1½ hours
Grand Canyon	1 hour

Bus or Train from Los Angeles

Carlsbad Caverns	1 day
Yosemite National Park	1 hour
Sequoia National Park	1 hour
Grand Canyon	2 days
Death Valley	1 day
Palomar Observatory (home of the 200-in telescope)	4 hours

What about the money for these trips? That's easy. After attending our meeting, with its numerous committee meetings, very extensive technical program (over 30 full sessions), industry luncheons, and more, you will go back to work so chockful of good ideas that the boss will immediately give you a raise which will easily cover your vacation expenses. Try it.

Perhaps we should point out that due to the popularity of some of these "side trips" from Los Angeles, or indeed from anywhere else, reservations with the transportation company should be made well in advance.

C. M. Wakeman,

Chairman, General Committee on Arrangements

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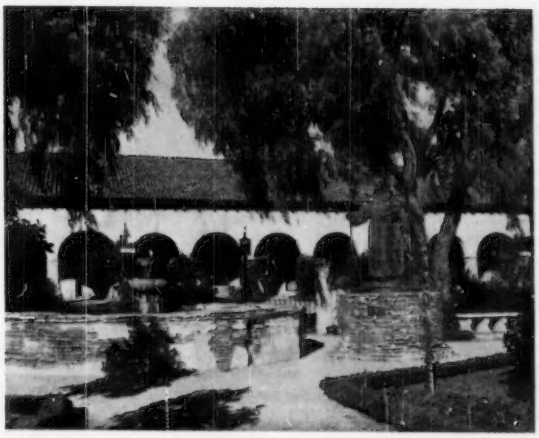
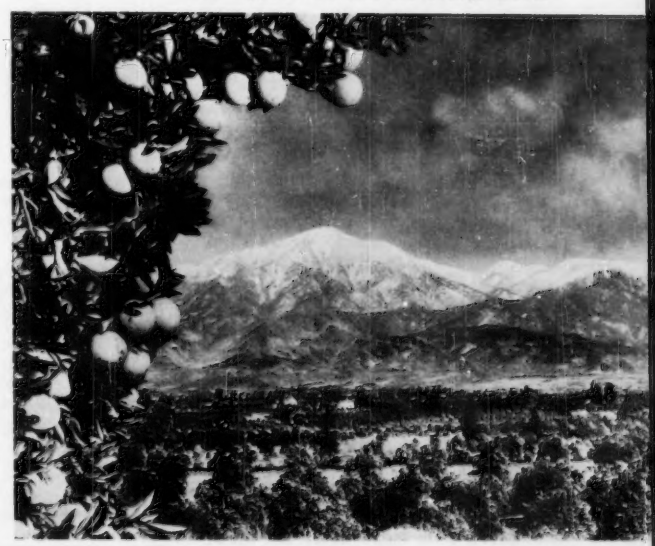


Snow-Capped Mountains and Orange Groves



NEW ASTM PUBLICATIONS

1955 Book of Standards Will Be Completed Earlier than ever Before

THE 1955 Book of Standards is something special—the biggest ever. And with the publication and distribution of the last Part (Part 6) by the end of this month it will be completed the earliest ever after an Annual Meeting. To fulfill the expressed desire of the Board of Directors and of the Staff also, special efforts were made throughout the past year to complete and publish the 1955 Book as early as possible and to put it to work in industry. The Herculean task was accomplished by careful planning, coordination, and cooperation over a period of almost a year—cooperation involving the technical committees, the Staff, the printer, two different binderies, the paper manufacturer, and transportation companies.

Early in 1955, technical committees were asked to plan their work on new standards and revisions so that it would be completed and ready for action at the Annual Meeting. Last minute changes and "hold outs" were discouraged. The letter ballot was prepared and mailed promptly after the Annual Meeting and canvassed as soon as possible. In the meantime, the mechanics of the printing and binding were explored thoroughly and a take system worked out with the printer under which a specified amount of material (150 pp.) was delivered to the printer every day. Paper needs were estimated early, the contract for purchase completed, and schedules for delivery established. By the time the ballots were counted in September, presses were already rolling on portions of the books that were released. At the same time, further coordination permitted the printing and publication of many compilations concurrently with the Book of Standards. Many of these have been completed and are already in use.

Special Paper Used

While the size of the book has been held to 7 Parts, several Parts have reached the maximum practical size for handling, Part 1 containing 1834 pages plus inserts is now $2\frac{1}{2}$ in. thick. Part 3 containing 2056 pages is $2\frac{5}{8}$ in. thick, "about as big as a volume ought to be;" and the book has been kept within these sizes only because of the use of a special bible paper purchased by the Society to conserve weight and shelf space. The 1955 edition is printed on 30-lb bible paper of greater firmness and opacity than the 26-lb paper used in the 1952 edition, where the printing showed through the page slightly—a somewhat undesirable result of our first experience with bible paper. The work involved in producing the Book of Standards and the quantities of materials and time involved are a testimonial to the unselfish work of the Society's members and committee members and to the thousands upon thousands of man hours of work and effort that have contributed to the development of the standards.

A Huge Investment of Time

The Society is investing about $235,000 in the actual printing and distribution—and this is but a small portion of the total dollar value of the time and effort and research and knowledge and experience which go into the development of standards comprising the book.

But, as with any investment—machines, tools, buildings, industrial plants—the Book of Standards becomes valuable only as it is used. Its wide distribution and use throughout the world and especially in the United States and Canada is a source of gratification to the technical committee men who have given so generously of their time and thought and effort in producing standards.

The Book of Standards can be as valuable and useful as it is only because of the confidence placed in its reliability. Again credit is due the committees for their constant vigilance in keeping abreast of the needs in all fields of materials for new standards and for the revision of existing standards to see that they keep in accord with progress and that new ones are added to fill the gaps which may become evident as new techniques and materials come into being.

Production executives, materials engineers, designers, architects, purchasing agents, and all others concerned with specifying engineering materials should bring their references to ASTM standards up to date. In doing this they will benefit from the combined knowledge and experience of the thousands of volunteer authorities who make up ASTM and serve on its committees.

The reference value of the Book of Standards cannot be overemphasized. Although in many circumstances one or two Parts of the Book of Standards pertaining to the specialty of the engineer or corporation may be adequate for 90 per cent of the problems which arise, having a complete book on hand for the

1955 BOOK OF STANDARDS PRICES

		*Members for Extra Copies**	*Nonmembers*
Part 1	Ferrous Metals	$10.00	$13.50
Part 2	Non-Ferrous Metals	8.50	11.00
Part 3	Cement, Concrete, Ceramics, Thermal Insulation, Road Materials, Waterproofing, and Soils	10.00	13.50
Part 4	Paint, Naval Stores, Wood, Fire Tests, Sandwich Constructions, Building Constructions	8.50	11.00
Part 5	Fuels, Petroleum, Aromatic Hydrocarbons, and Engine Antifreezes	8.50	11.00
Part 6	Electrical Insulation, Electronic Materials, Plastics, Rubber	9.00	13.00
Part 7	Textiles, Soap, Water, Paper, Adhesives, and Shipping Containers	8.50	11.00
Complete Set		63.00	84.00

* Each member gets one selected Part on his membership and can procure the other Parts and Supplements at an annual charge of $3 per Part.

other 10 per cent would be of great value and justify the relatively few more dollars spent annually to obtain a complete set.

Members receive on their membership any one Part and its Supplements without extra charge. Many have elected to receive on a continuing basis two, three, or more additional Parts and Supplements at an annual charge of $3 per Part. About 40 per cent of our members get all seven Parts. The members' instructions in this regard are kept on file at ASTM Headquarters and shipments of the Book of Standards and its Supplements are made automatically against these instructions. Members also have the privilege of buying extra copies at prices considerably under the list price.

Standards on Petroleum Products

THIS special compilation of ASTM specifications, tests, and definitions covering petroleum products and lubricants is one of the most widely distributed ASTM publications—an indication of the intense interest in evaluating the properties and quality of a wide range of petroleum products. It provides in compact, readily usable form the well-used ASTM standards in this field. Sponsored by ASTM Committee D-2 on Petroleum Products and Lubricants, the book has been issued annually since 1927.

The 1955 edition gives in their latest approved form a total of 170 test methods, specifications, and lists of definitions. Two Tables of Contents are included, one an extensive classified listing of the standards according to the subjects covered, the other a numeric listing by ASTM serial designations. A useful index is also provided.

In addition, several appendices are included covering the following proposed tests which are published as information only: Emulsion Stability of Soluble Cutting Oils; Galvanic Corrosion Associated with Instrument Lubricating Oils; Blocking Point of Paraffin Wax; Oxidation Stability of Paraffin Wax (Peroxide Method); Vanadium in Residual Fuel Oil; Estimation of Heat of Combustion of Liquid Petroleum Products; Tetraethyllead in Gasoline by Direct-Reading Polarograph; Consistency of Semifluid Greases; Estimation of Deleterious Particles in Lubricating Grease; Benzene, Toluene, Ethylbenzene, and Individual Xylenes by Infrared Spectrophotometry; Measuring the Color of Petroleum Products; and Water in Bituminous Materials.

Also to be found in the compilation are List of Proposed Methods Prepared by Committee D-2 and Published as Information Prior to 1955; List of Other ASTM Publications on Petroleum Products and Lubricants; and the latest D-2 Annual Report.

The methods of test for knock rating of engine fuels are issued in two special volumes and are not included in this compilation; also the several standards for measuring and sampling petroleum are not included, these appearing in the ASTM Manual on Measurement and Sampling Petroleum and Its Products. Procedures for Calibrating Liquid Containers are also published separately.

This 1000-page book can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. Price: $6.50; to members, $4.85. For cloth covers, add 65 cents to these prices.

Infrared Spectral Absorption Index Cards

THERE is now available a second supplement to the ASTM-Wyandotte cards indexing infrared spectra. The supplement consists of 2038 cards, which index spectra from the following sources:

Source	*Number of Cards*
Samuel P. Sadtler and Son, Inc.	1400
American Petroleum Inst.	27
National Research Council	199
Abstracted from literature	252
Reissues (corrections, etc.)	160
Total	2038

The price of this supplement is $25.50.

For those who are purchasing a deck of infrared index cards for the first time, there are now available complete decks consisting of 10,969 cards, which index spectra from the following sources:

Source	*Number of Cards*
Samuel P. Sadtler and Son, Inc.	7 215
American Petroleum Institute	976
National Research Council	438
Abstracted from literature	2 340
Total	10 969

The price of a complete deck is $137.50 and includes a copy of the book of "Codes and Instructions for Wyandotte–ASTM Punched Cards Indexing Spectral Absorption Data."

They can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia, Pa.

Panel Session on Pyrometry

A PANEL session on pyrometric practice in elevated-temperature testing, sponsored by the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals and organized by the Test Methods Panel of that group, was held at the ASTM Annual Meeting in June, 1955. The papers and discussion arising from this meeting are now available as an ASTM Special Technical Publication.

The subject of the discussion was the ASTM Recommended Practices on high-temperature testing of metals: Short Time Elevated-Temperature Tension Tests of Metallic Materials (E 21); Conducting Long-Time High-Temperature Tension Tests of Metallic Materials (E 22); Conducting Time for Rupture-Tension Tests of Metallic Materials (Tentative) (E 85). Much interest centers in defining the precision of temperature measurement and control which can be recommended or specified in high-temperature test work.

One formal paper by J. M. Berry and D. L. Martin, General Electric Co., entitled "Thermocouple Immersion Errors," and two formal written discussions by C. R. Wilks and W. E. Leyda, American Brake Shoe Co., were presented and appear in this volume. Other discussion leaders of the panel were W. F. Roeser, National Bureau of Standards, P. H. Dike, Leeds & Northrup Co., and J. R. Freeman, University of Michigan, who has campaigned persistently in the Joint Committee for a rationale of temperature measurement in creep and rupture testing.

Copies of this 56-page publication, *STP No. 178*, can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. Price: $1.50; to members, $1.15.

Bibliographical Abstracts on Evaluation of Brightening Agents for Detergent Usage

BRIGHTENING agents are essentially colorless dyes which, when applied on textiles, absorb ultraviolet irradiation and emit light of a blueish hue complementary to the yellow tint already present on the off-white substrate. In this manner the brightening agents impart a greater apparent whiteness to the materials treated. Although brighteners were originally applied to paper, they were incorporated in detergent compositions about 1945. The growth of this application has

expanded to the point where brightening agents are available for most types of fiber and detergent compositions. The literature has grown so that a bibliography of the published methods was desirable. This bibliography has been prepared by Lloyd E. Weeks, of the Monsanto Chemical Co., a member of Subcommittee T-5 on Physical Testing of ASTM Committee D-12 on Soaps and Other Detergents.

Thirty-seven titles and abstracts are included. References are numbered consecutively and are listed by year and then by author or by journal if the article is anonymous. Copies of the 9-page bibliography (*STP No. 177*) can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa. Price: $1.50.

Abandonment of Master Saybolt Viscometers as Standards

THE National Bureau of Standards announces its intention to abandon after June 30, 1956, the use of the master Saybolt viscometers as standards for the calibration of Saybolt Universal and Saybolt Furol viscometers. Saybolt viscometers are widely used in the petroleum industry to measure viscosities of lubricating and fuel oils.

Many years ago, these master instruments were adopted in cooperation with the American Petroleum Institute's Committee on Viscosity Standards, as representing Saybolt instruments having normal flow times. The master instruments have been in the custody of the National Bureau of Standards where they have been used to determine corrections to be applied to the flow times of instruments submitted for certification.

More recently, the ASTM has published standard conversion tables and factors for the conversion of kinematic viscosities to Saybolt viscosities. Because of the greater precision possible in determining kinematic viscosities, these tables and factors provide more precise definitions of the Saybolt viscosity scales than do the master instruments. Consequently, continued use of the master instruments has become unnecessary and technically undesirable.

Any objections to this proposed action should be brought promptly to the attention of the Director of the National Bureau of Standards.

Symposium on Metallic Materials for Service at Temperatures above 1600 F

A Critical Problem Surveyed

ENGINEERS charged with the construction of guided missiles have many problems, the solution of which is dependent upon the availability of metals with the necessary strength at temperatures above the present 1600 F limit. Less spectacular than the development of the hitherto undreamed of intercontinental pilotless missiles but equally as important is the quest for greater efficiency in power engineering which creates a never-ending demand for metals capable of withstanding the higher operating temperatures required.

Steam power plant designers are pushing temperatures and operating pressures beyond the safe limits of strength and endurance of the ferritic steels which have been used in such installations. Gas turbine engineers state that they are prepared to design for operations at temperatures higher than the 1600 F limit to which they have been restricted.

The vital necessity of solving these problems has brought forth within the last year two symposiums, sponsored by the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals. The first, "Basic Effects of Environments on the Strength, Scaling and Embrittlement of Metals"[1] was held early in 1955 during ASTM Committee Week. The second, "Metallic Materials for Service at Temperatures above 1600 F" was arranged for the Society's Annual Meeting in June, 1955 and it is these papers that appear in the present publication.

The problem of high-temperature strength of various alloys and *of their stability* was attacked from several directions. Thus, a number of authors reported properties of nickel, cobalt, and molybdenum-base alloys; other metallurgical researchers sought a solution through the application of carbides, powder metallurgy techniques (for the production, for example, of high-temperature molybdenum-base alloys), while some described the effectiveness of ceramic coatings for protection of metal against oxidation and erosion.

That these papers report progress in a wide variety of approaches to a solution can be seen from a perusal of the titles:

Introduction—*V. R. Krivobok, International Nickel Co.*

Some Sheet and Bucket Materials for Jet-Engine Application at 1600 F and Higher—*J. P. Denny, L. P. Jahnke, E. S. Jones, and F. C. Robertshaw, Jr., General Electric Co.*

Influence of Boron on Cast Cobalt-Base S-816 Alloy—*W. E. Blatz, E. E. Reynolds, and W. W. Dyrkacz, Allegheny Ludlum Steel Corp.*

Effect of Heat Treatment and Structure upon Creep Properties of Nimonic Alloys Between 750 and 950 F—*W. Betteridge and R. A. Smith, The Mond Nickel Co., Ltd.*

Stress-Rupture Properties of Inconel 700 and Correlation on the Basis of Several Time-Temperature Parameters—*S. S. Manson and G. Succop, National Advisory Committee for Aeronautics*

Chromium-Nickel Alloys for High-Temperature Applications—*A. G. Bucklin and N. J. Grant, Massachusetts Institute of Technology*

Effect of Rare Earth Additions on the High-Temperature Properties of a Cobalt-Base Alloy—*J. E. Breen and J. R. Lane, Naval Research Laboratory*

Creep, Rupture, and Notch Sensitivity Properties of S-816 Alloy up to 1650 F under Fatigue and Static Stress—*F. Vitovec and B. J. Lazan, University of Minnesota*

Titanium-Carbide-Base Cermets for High-Temperature Service—*K. Pfaffinger, Metallwerke Plansee, H. Blumenthal, American Electro Metal Corp., and F. W. Glaser, Alloy Precision Castings Co.*

Titanium-Carbide Products Produced by the Infiltration Technique—*L. P. Skolnik and C. G. Goetzel, Sintercast Corp. of America*

High-Temperature Properties of Molybdenum-Rich Alloy Compositions Made by Powder Metallurgy Methods—*W. L. Bruckart, Universal-Cyclops Steel Corp. and R. I. Jaffee, Battelle Memorial Inst.*

Tension and Torsion Tests on Nimonic Alloys at High Temperatures—*E. D. Ward and W. G. Tallis, The Mond Nickel Co., Ltd.*

Thermal Shock Testing of High-Temperature Metallic Materials—*T. A. Hunter, University of Michigan*

Copies of this 200-page symposium, *STP No. 174*, with discussions, can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia, Pa. Price: $3.50; to members, $2.65.

[1] Published by the American Society for Testing Materials and available from Headquarters, 1916 Race St., Philadelphia, Pa.

Book of Standards Statistics Are Startling

This is what it took to publish the 1956 Book of ASTM Standards:

Number of pages	11 784
Paper, lb	274 000 (7 carloads)
Press time, hr	3 000
Total number of books	90 100
Press pages	153 200 000

"He Stole the Fire from Heaven"

Franklin in Marble

The Benjamin Franklin Memorial, The Franklin Institute, Philadelphia

IN 1753 the Royal Society announced that Benjamin Franklin was the recipient of the Sir Godfrey Copley Gold Medal, by virtue of his "curious experiments and observations on electricity . . . and as deserving well of the philosphical world and of this learned body in particular."

At the age of 42, Franklin had retired from his printing business in Philadelphia and plunged actively into politics and natural philosophy. Had Franklin exerted his energies solely in the field of politics, his name would be revered only as one of the brilliant statesmen who, out of the chaos of colonial insurrection, helped to forge a nation based upon the most advanced ideals of individual freedom.

Franklin had, however, an inquisitive mind and, as his sphere of governmental activity increased, his contacts with men active in the field of natural philosophy also increased. He had correspondence and personal contact with Priestley, Cavendish, and Lavoisier. He was therefore familiar with the new ideas concerning the properties of matter and was able by experimental research and by suggestion to assist in the development of the theories of light and heat which were already shaping toward the modern doctrine of the forces of nature. Lavoisier invited him to his laboratory when a new and important experiment was being tried. Priestley consulted him at every step, as he groped his way to a more perfect understanding of the nature of gases. In his "Experiments on Air," Priestley published the letters he had received from Franklin, which opened new horizons to him and set him upon novel ways of thought and experiment. In one of these letters, dated April 10, 1774, Franklin gave what is perhaps the earliest clear account of marsh-gas. This account was the result of experiments carried out in the rivers of New Jersey as early as 1764.

Experiments that he had not the time or means of making he constantly recommended to his philosophical acquaintances. Many of these ideas were carried to brilliant conclusion by his contemporaries.

In France he witnessed the first balloon ascensions with Sir Joseph Banks, president of the Royal Society. Shortly thereafter he wrote concerning the military use of such a conveyance for carrying whole armies over hostile battlements.

Franklin held discussions with the outstanding men of his time concerning the nature of light and heat, experiments with oil on rough seas, newly invented vacuum pumps (he purchased one for Yale University), corresponded with Herschel and Maskelyne concerning sun spots and nebula. He wrote a dissertation on the Gulf Stream based upon thermometrical observations made during trips to Europe. Further, he assisted European scholars in their studies of the nature of the native languages of America and the ethnology and archaeology of the country. He purchased 300 acres of land near Burlington, N. J., to conduct agricultural experiments, and secured an appointment for John Bartram as American botanist to George III.

Notwithstanding all the major and minor contributions to the philosophical world of that time, Franklin is best remembered for his studies of electricity. In this field he was a pioneer. He improved the Leyden jar and the electrostatic generating machines and conceived electricity as one electric fluid having the property of being negative or positive. By clever simple experiments, he proved the identity of electricity and lightning, thus providing the experimental basis for the lightning rod.

To those who could neither read nor understand the eager gropings of the natural philosophers into the physical and chemical world, the dramatic experiments with lightning were without parallel. Armed with this knowledge, all men could protect themselves, their homes, their farms and ships against the most terrifying phenomenon of the universe. Franklin's fame reached into the far corners of the earth; honor upon honor was bestowed upon him. Oxford, St. Andrew's, Harvard, Yale, and William and Mary granted him honorary degrees and the Royal Society offered him honorary membership. The award of the Copley Gold Medal placed Franklin among Priestley, Cook, Herschel, and Volta of his own time and Pavlov, Einstein, Bragg, and Bohr of ours.

But to the ordinary citizen he was, as Kant said, "a new Promoetheus who had stolen the fire from Heaven."

ASTM Bulletin

FEBRUARY 1956

NO. 212

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

ASTM Finances in 1955

THE BEST way to describe the year is to say that in the opinion of the Finance Committee and Directors it was a very encouraging one.

The budget anticipated an operating deficit of $59,000; instead we ended up with a very small favorable balance. Details of the year were given to the Board of Directors at its January 17 meeting, and the financial picture will be spelled out, as customary, in the Annual Report of the Board of Directors to the Society at the meeting in Atlantic City the week of June 17.

1955 Income

Receipts reached an all-time high of $852,000. A most favorable membership year, with over 700 new members added helped materially, but the most significant figure was total sale of publications, $521,500. With improved BULLETIN advertising income, as well as interest and dividends, miscellaneous receipts totaled $78,500—good for a year in which there was no income from exhibits.

The Directors noted the trend in recent years whereby publications gradually are providing the larger portion of our income, but they recognize that this is not due to decreased membership, but rather to wider demands for the information and data given in the standards and our multitude of technical publications. The sale of these books is vital to our operations, but more significant, they result in increased use of standards.

The percentage of income from dues and publications is shown in the accompanying table. Comparison of items from one year to another will show the relative situation.

1955 Costs

Costs were higher in 1955. They almost kept pace with income, but this was not unexpected. One item alone, in the petroleum field—an interesting visual comparison standard for copper strip corrosion tests—cost over $30,000 (but it is rapidly paying for itself).

Publication costs were almost $350,000, which includes $100,000 as a portion of the 1955 Book of Standards costs. The balance to cover this big book comes from funds earmarked from the two previous years.

Publications represented 41.2 per cent of total costs.

In 1955, 35.8 per cent of our disbursements were for salaries, including extra clerical help and overtime. There was nothing startling in other items of expense, but obviously as the Society grows, handling a tremendous volume of publications and other matters, in addition to a steadily expanding technical work, its costs will increase. Every effort is made to place our operations on as efficient a basis as possible through mechanization and simplification of records and reports.

Headquarters Building

The general operating funds continue to pay into the building fund a reasonable amount for depreciation and amortization, both considered part of occupancy expenses. Amortization is based approximately on a ten-year period, but actually is being accelerated.

OPERATING RECEIPTS

Source	1955		1954		1953		1952	
		Per cent		Per cent		Per cent		Per cent
Dues	$252 072	29.6	$236 345	29.8	$233 705	28.7	$226 284	34.9
Sales of Publications	521 496	61.3	470 459	59.2	512 262	62.9	338 448	52.2
Miscellaneous								
Advertising	31 994	...	28 214	...	28 398	...	30 607	...
Interest and Dividends	27 162	...	23 754	...	21 956	...	19 264	...
Registration Fees	13 701	...	12 581	...	13 768	...	14 277	...
Exhibit	750	...	16 144	...	1 355	...	16 243	...
Other	4 628	...	7 048	...	3 196	...	3 320	...
Total Miscellaneous	78 235	9.1	87 741	11.0	68 673	8.4	83 621	12.9
TOTAL RECEIPTS	$851 803	100.0	$794 546	100.0	$814 640	100.0	$648 523	100.0

OPERATING DISBURSEMENTS

Item	1955		1954		1953		1952	
		Per cent		Per cent		Per cent		Per cent
Publications	$349 963†	41.2	$277 346*	36.9	$263 811*	44.9	$259 823	41.9
Salaries	305 362	35.8	276 855	36.9	237 761	33.0	211 817	34.2
General Office Expense	83 342	9.8	79 802	10.6	75 773	10.5	60 475	9.7
Meetings and Technical and District Committees	27 121	3.2	33 270	4.4	23 253	3.2	31 335	5.0
Headquarters Occupancy	35 319	4.1	31 035	4.2	21 658	3.0	24 001	3.9
Retirement, Health	32 855	3.9	27 429	3.6	21 070	2.9	16 013	2.6
Miscellaneous	17 390	2.0	25 250	3.4	17 797	2.5	16 566	2.7
TOTAL DISBURSEMENTS	$851 352†	100.0	$750 987*	100.0	$661 123*	100.0	$620 030	100.0

* Does not include $60,000 earmarked as a reserve for the 1955 Book of Standards, and not expended.
† Includes $100,000 earmarked for the 1955 Book of Standards. This, together with $120,000 from the two previous years, earmarked but not spent, really spreads the cost of this Book over a three year period.

Unquestionably the value of our buildings in Philadelphia is enhanced each year by developments in the general area. Within two years it is expected that one of our neighbors, the Moore Institute of Art, will have completed its $3,000,000 classroom and dormitory buildings.

Assets and Surplus

The auditors report shows that our assets grew about $100,000 over the previous year. There was a modest addition to surplus of about $53,500, but the ratio of surplus to annual disbursements is still under 50 per cent, specifically 44.7.

Investments

Continued progress has been made in putting more of the Society's available dollars to work. This year all of our several funds were consolidated into one investment fund, which is allocated to the various funds, such as building, research, etc., in accordance with their percentage of equity in the capital, and also in interest and dividends. As of December 9, the close of our year, market value of investments was about $732,600, book value about $547,300. In addition the fund also has to its credit about $165,000 cash. As this fund grows it requires increasing attention of the Finance Committee and of the Executive Secretary, and negotiations are now under way to engage investment counsel to supplement the wide knowledge of those on our Finance Committee and the Board, and also the Investment Advisory Committee.

The progress made in improving the Society's investments has been an important part of our financial operations in the past two years.

1956 BUDGET SUMMARY

		Per cent
Estimated Receipts		
Dues and Entrance Fees	$256 000	26.5
Publications	604 000	62.3
Miscellaneous	107 500	11.2
TOTAL CURRENT RECEIPTS	$967 500	
Estimated Disbursements		
Publications	$359 000	38.4
Salaries	327 000	35.0
General Office Expenses	93 000	10.0
Technical Committee Expenses	13 500	1.5
Meetings	40 000	4.3
Headquarters Occupancy Expenses	40 000	4.3
Retirement, Health	38 000	4.0
Miscellaneous Expenses	23 000	2.5
TOTAL OPERATING DISBURSEMENTS	$933 500	

Income—$851,803.50
(Our best membership year and heavy distribution of books built this up in a gratifying way.)
Spent—$851,351.82
(Publication costs continue very heavy, but to achieve our purpose we must publish and disseminate data widely.)
Net—An almost insignificant favorable balance of $451.68.
(This is much better than the budged deficit of $59,000.)
Total Assets—$1,344,744
(This is up about $100,000. A better investment picture helped.)
Surplus—$380,494
(While this is higher, it still represents only 44.7 per cent of annual disbursements—less than six months operations.)

1956 Budget

1956 is the year when we expect very heavy returns from the sale of the new Book of Standards. From the accompanying table entitled "Budget Summary" it will be seen that our total income is expected to reach $967,500, of which 62.3 per cent, or $604,000, will come from distribution of publications. Unusual expenses are coming up, including provisions for the West Coast meeting, but the Finance Committee is hopeful that the total will not exceed $933,500, leaving a modest $34,000 favorable balance.

Directors' Regulations Revised

REVISIONS have been adopted recently by the Board of Directors affecting certain portions of its Regulations. As a result of detailed study it was apparent that portions of these Regulations, which are really supplemental to the Bylaws of the Society, could be modernized and some operations put on a more realistic basis.

The Bylaws state that the general management of the Society shall be vested in the Board of Directors and spell out information on meetings, quorum, appointment of an Executive Committee, and other details. The Regulations cover a number of other areas, such as subcommittees, reports, information on finances, etc. Formerly published in the Year Book, these Regulations are not included in the current edition (in order to reduce the size of the book) but have been duplicated and a copy will be sent to any member or committee member on request.

Summary of Changes

From time to time special committees of the Board need to be appointed in addition to the standing subcommittees shown in the forefront of the Year Book. This procedure has been formalized. At the same time the number of members for the Board committees was increased.

Perhaps the major changes in the Regulations relate to the handling of financial matters. Under the former regulations no bills were to be paid without approval by the chairman of the Finance Committee. Actually, by separate agreement, the Treasurer was able to obtain discounts and take care of certain large bills. The latest provisions provide that after approval by the Staff members responsible for an expenditure and finally by the offices of the Treasurer and the Executive Secretary or Associate Executive Secretary, bills shall be paid and the chairman of the Finance Committee shall then review and approve. The Regulations state that any member of the Finance Committee can examine bills and vouchers prior to payment if he desires. Formerly, all vouchers went to the chairman but now none under $200 are submitted; instead a summary schedule lists all of these. Provision has been included that while as formerly all committee bills are to be paid only after approval of the chairman of the technical committee concerned, now it is specific that an authorized member of the Staff must also approve and these vouchers are also to be reviewed by the Finance Committee chairman.

The Directors after careful consideration felt that the revised Regulations would provide for somewhat smoother operation, and this has been borne out in the few months since they were changed.

Meetings Streamlined

It might be appropriate to mention also that during the past 18 months written reports sent in advance to the Board are not presented in detail, but are covered in reports by the chairmen of the respective committees—membership, finances, etc.—thus pro-

viding more time in the meeting for discussion of policy and related matters. At each Board meeting there is a general discussion of some significant area of the Society's work or of what appears to be a future problem so that members might present their reactions informally. Such discussions have led to some very interesting and contructive developments.

As the work of the Society has grown in all branches, so have the responsibilities of the Directors. The agendas for the meetings of the subcommittees preceding the full-day meeting of the Board are full, and each of the three two-day meetings held during the year are busy ones. Down through the years the attendance at these meetings has been exceedingly high, bespeaking the close attention given by the Directors to their responsibilities. While election to the Board of Directors is considered a high honor, it carries with it much responsibility and the devoting of considerable extra time to the work of the Society.

ASTM Begins Coordinating Work on Nuclear Engineering Materials and Fuels

THE ASTM Special Administrative Committee on Nuclear Problems held its first meeting on January 16, with a large majority of the members of the Board of Directors as an interested audience. Members of the Special Administrative Committee appointed by President Fellows are as follows:

N. L. Mochel (chairman), manager, metallurgical engineering, Westinghouse Electric Corp.
G. D. Calkins, assistant division chief, Battelle Memorial Institute
C. L. Clark, research metallurgical engineer, Timken Roller Bearing Co., Steel and Tube Division
M. A. Cordovi, Babcock & Wilcox Co.
G. M. Kline, chief, Division of Organic and Fibrous Materials, National Bureau of Standards
F. L. LaQue, vice-president and manager, Development and Research Division, The International Nickel Co., Inc.
F. C. Linn, ANP Project, General Electric Co.
J. C. Robinson, chief, Engineering Development Branch, Division of Reactor Development, United States Atomic Energy Commission
L. P. Spalding, chief research engineer, North American Aviation, Inc.
J. R. Townsend, director, material and standard engineering, Sandia Corp.
H. A. Wagner, The Detroit Edison Co.

The scope of the committee will be (1) to advise with the technical committees of the Society on nuclear problems pertinent to their respective scopes, (2) to stimulate the undertaking of research and standardization projects, specifically related to nuclear energy, on the part of the technical committees, and (3) to review periodically the status of the work.

As a first step in coordination, ASTM Committee E-10 on Radioactive Isotopes is being asked to consider expanding its title and scope to investigate, promote, and advise on techniques and standards for measuring changes in properties and constitution of materials as a function of radiation exposure. The Special Administrative Committee agreed that basic procedures for specimen preparation, exposure to radiation, and special techniques for measuring properties after exposure could be developed by Committee E-10.

The Atomic Industrial Forum and Committee E-10 will also jointly sponsor a symposium on radiation effects at the ASTM West Coast National Meeting this coming September. Additional papers sponsored by Committee E-10 on radioisotope uses will be included in this extensive symposium.

The Special Administrative Committee also agreed to establish a list of materials used in reactors as a basis

Schedule of ASTM Meetings

This gives the latest information available at ASTM Headquarters. Direct mail notices of all district and committee meetings customarily distributed by the officers of the respective groups should be the final source of information on dates and location of meetings. This schedule does not attempt to list all meetings of smaller sections and subgroups.

DATE	GROUP	PLACE
Feb. 27–March 2	**Committee Week**	**Buffalo, N. Y. (Statler)**
March 1	Meeting of New Orleans Members	New Orleans, La.
March 5	Joint Meeting—Southwest District and American Institute of Electrical Engineers	Houston, Tex. (University of Houston)
March 8	Joint Meeting—Southern California District and American Society of Mechanical Engineers	Los Angeles, Calif.
March 13	Joint Meeting—Northern California District and American Institute of Electrical Engineers	San Francisco, Calif. (Rodger Young Auditorium)
March 13	Joint ASTM-ALCA Committee on Leather	Philadelphia, Pa. (ASTM Headquarters)
March 13–16	D-13 on Textile Materials	New York, N. Y. (Warwick)
March 13–14	Joint ASTM-SAE Committee on Automotive Rubber	Detroit, Mich. (Rackham Memorial)
March 19	Meeting of Salt Lake City Members	Salt Lake City, Utah
March 19–20	D-12 on Soaps and Other Detergents	New York, N. Y. (Park Sheraton)
March 22–23	D-15 on Engine Antifreezes	Washington, D. C. (Shoreham)
March 22	Joint Societies' Meeting	Richland, Wash.
March 23	Joint Societies' Meeting	Spokane, Wash.
March 27	Joint Meeting—ASTM Portland Members and American Society for Metals	Portland, Ore.
March 29	Meeting of Vancouver Members	Vancouver, B. C.
April 4–6	D-14 on Adhesives	Louisville, Ky.
April 5	Meeting of Toronto Members	Toronto, Ont., Canada
April 11	Chicago District	Chicago, Ill. (Western Society of Engineers)
April 11–12	D-10 on Shipping Containers	Atlantic City, N. J. (Claridge)
April 22	C-21 on Ceramic Whiteware and Similar Products	New York, N. Y. (Statler)
April 25	Detroit District	Detroit, Mich. (Eng. Soc. Bldg.)
April 26	Pittsburgh District	Pittsburgh, Pa.
April 30–May 1	C-20 on Acoustical Materials	Philadelphia, Pa. (ASTM Headquarters)
June 17–22	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

for future technical committee activities. Another project is the gathering of information from the technical committees on current and planned activities regarding engineering materials in nuclear reactors (including nuclear fuel effects) as well as the property changes in engineering materials exposed to nuclear radiation.

Executive Secretary Painter cuts his 25th Anniversary cake at Staff dinner. Seated at the head table, in the usual order, are Marie Ounan, Mary Dickson, and George Wilson of the ASTM Staff; Mrs. Raymond Hess, wife of the Associate Executive Secretary; half hidden is Florence Artis of the Staff, next to Mr. Painter; Raymond Hess, who was master of ceremonies for the occasion; Mrs. Painter; and Paul J. Smith, of the Staff.

Twenty-Fifth Anniversary Dinner for R. J. Painter

On January 19 a dinner was given by the Staff to congratulate Robert J. Painter on having attained 25 years' service to the Society, first as a Technical Assistant, later as Assistant Secretary, and presently as Treasurer and Executive Secretary. Although the actual anniversary date is February 16, the dinner was given in advance so as to come as a complete surprise.

The dinner, held at the Robert Morris Hotel in Philadelphia, was attended by over 70 members of the Staff plus a number of their wives and husbands.

Following the dinner, the 25-year Staff members gave an amusing and appreciative discussion of Mr. Painter's qualifications for admittance to their number. These informalities set a delightful pace for an enjoyable evening. The Board of Directors presented Mr. Painter with a piece of airplane luggage as a token of appreciation of his 25 years service.

Mr. Painter graduated as a civil engineer from Rensselaer Polytechnic Institute in 1928, joined the Society's Staff in February, 1931. His early work with the Society included management of the exhibit of testing apparatus, developmental and promotional work, including membership and publication sales. He also devoted much time to the ASTM Bulletin, becoming the Associate Editor and Business Manager. Mr. Painter also served as Technical Assistant and later Secretary of Committee A-1 on Steel.

In April, 1952, he was appointed Treasurer upon the retirement of J. K. Rittenhouse, and in September, 1952, he was appointed Executive Secretary upon the death of C. L. Warwick.

Mr. Painter is the ninth member of the present Staff having 25 years service with the Society. Those who have been previously recognized are: Marie A. Ounan, R. E. Hess, G. A. Wilson, Dorothy E. Hand, Florence Artis, P. J. Smith, Mary E. Dickson, and Mildred Odiorne.

Members of the Staff's 25-Year Club. Standing, left to right: Paul J. Smith, Standards Editor; Robert J. Painter, Executive Secretary and Treasurer; Raymond E. Hess, Associate Executive Secretary, Technical Secretary and Editor; and George A. Wilson, Senior Assistant Editor; The ladies, seated, left to right are: Mildred Odiorne, Secretary; Marie A. Ounan, Secretary, Directors; Dorothy E. Hand, In Charge, Publication Orders and Shipping; Mary E. Dickson, In Charge, Membership and Committee Records. Absent when the picture was taken and shown in the insert, is Florence Artis, Secretary.

President Fellows on Speaking Tour of West Coast

THE West and Southwest are preparing to roll out the red carpet for President Claire H. Fellows as he and Executive Secretary R. J. Painter make final arrangements for a four to five week trip in these areas.

President Fellows will present variations of his address "Research in the Electric Power Industry" and will include the latest developments on high-voltage aluminum cable and extra high-voltage cable; wood preservation—poles, crossarms, etc.; corrosion (especially galvanized steel tower transmission); tree growth control; fish fences; insulating oils; hydrocarbons—fundamental research aspects; and nuclear power.

The two officers will start their trip with a dinner meeting in New Orleans on March 1 and from there, as follows:

March 5....Houston, Tex.
March 8....Los Angeles, Calif.
March 13...San Francisco, Calif.
March 19...Salt Lake City, Utah
March 22...Richland, Wash.
March 23...Spokane, Wash.
March 27...Portland, Ore.
March 29...Vancouver, B.C., Canada

Returning they will attend a meeting of ASTM members in the Toronto area on April 5. Subsequently the President will speak before the Chicago District on April 11; Detroit, April 25; and Pittsburgh, April 26.

Most of these meetings will be joint ones with local chapters of such groups as ASME, AIEE, ASM, and others.

Annual Conference for Engineers

THE College of Engineering at the Ohio State University announces its Annual Conference for Engineers (ACE) to be held in Columbus at the Ohio Union on May 4, 1956. Discussions and conferences concerning significant new developments and concepts in the various fields of engineering will be presented by staff members of The College of Engineering and selected industrial personnel. Program announcements will be released shortly.

The 1956 Conference is expected to surpass the record of last years' event which attracted more than 800 engineers from 21 states. Inquiries and reservations should be addressed to: Harold A. Bolz, Associate Dean, College of Engineering, the Ohio State University, Columbus 10, Ohio.

ASTM MEMBERS IN 60 COUNTRIES OTHER THAN UNITED STATES

A NATIONAL organization with international outgrowth, ASTM has 12½ per cent of its more than 8000 members scattered through 60 countries other than the U.S.A. The Membership Committee believes all members will be interested in the following statistics showing distribution of fellow affiliates in all parts of the world.

Argentina	22	Finland	2	Newfoundland	1
Australia	69	France	28	Norway	9
Belgian Congo	1	French Morocco	1	Pakistan	1
Belgium	32	Germany	20	Palestine	1
Brazil	36	Greece	7	Peru	4
British West Indies	1	Guatemala	1	Philippines	4
Canada	262	Haiti	2	Portugal	4
Chile	11	India	35	Saudi Arabia	2
China	6	Indonesia	3	Scotland	7
Colombia	14	Iran	1	Southern Rhodesia	1
Costa Rica	2	Ireland	2	Spain	14
Cuba	10	Israel	6	Sweden	42
Czechoslovakia	3	Italy	26	Switzerland	18
Denmark	7	Japan	24	Tasmania	2
Dominican Republic	2	Malaya	3	Thailand	2
East Africa	1	Mexico	44	Turkey	5
East Pakistan	1	Morocco	1	Union of South Africa	22
Ecuador	4	Netherlands	21	Uruguay	5
Egypt	7	Netherlands West Indies	1	Venezuela	26
England	174	New Zealand	14	Wales	1

We appreciate the interest of all who are represented in the above listing.

The Committee suggests to American members having business acquaintances in our immediate neighbor countries, overseas connections, or who are going on trips to other countries, that they send names of prospective members to Headquarters; and further invites current members in all countries to send names of their business associates or those in government departments, educational institutions, or scientific or trade groups who would be interested in receiving data on the research and standardization work of the Society.

N. A. FOWLER
Chairman, Directors' Membership Committee

Nike I and Transistors Described at New York District Meeting

THE New York District Council's first attempt at a series of programs to be sponsored by a particular industry made a highly successful start with "An Evening with the Bell Telephone Laboratories" on January 11, 1956.

Robert M. Ryder, transistor development engineer with Bell Laboratories described the various uses to which the transistor has been put, as well as some of its limitations. He discussed diodes of very high efficiency and moderately large power that have been made both by alloying and by diffusion. The stability of these units with time is about two orders of magnitude better than prewar electronic apparatus. Germanium transistors are used under maximum temperature limit of 150 F; above this temperature silicon is used. Silicon is not used for all, primarily because of its refining difficulties.

Mr. Ryder was introduced by R. Y. Atlee, chairman of the American Inst. of Electrical Engineers New York Section, Communications Div., co-sponsors of the meeting.

More spectacular, although not necessarily of greater importance, was P. H. Thayer Jr.'s presentation of "Nike I." A member of Bell Telephone Laboratories since 1936, Thayer is currently in charge of groups responsible for designing and engineering activity on the Nike I anti-aircraft guided missile system. His talk described the present day Nike I system, insofar as military restrictions would allow, with particular emphasis on the system philosophy and its achievement as a tactical AA defense weapon. He concluded his talk with a motion picture in color showing actual Nike missile flights and its effectiveness against aircraft using evasive techniques. George Gohn, also a member of Bell Laboratories and a past director of ASTM, introduced Mr. Thayer.

Both addresses were of interest to the more than 150 ASTM and AIEE members present, as evidenced from the extensive discussion which followed.

Preparations for this meeting were the results of efforts on the part of George Hiers and George Gohn of ASTM, and T. J. Talley and R. G. Ruwell of the AIEE. E. P. Pitman of the Port of New York Authority, Vice-Chairman of the ASTM New York District, presided.

ACR Notes

Administrative Committee on Research

The Importance of Unimportant Details

By W. H. Lutz[1]

COURT testimony is usually revealed as confusing and disjointed details that make little real sense until the case is finally summarized and interpreted in broad sweeping terms. ASTM committee work bears a striking resemblance to court procedure. Technical committees bore deeply into very specific and sometimes obscure details. When these details are reported for the benefit of specialists in the same field, outsiders may experience difficulty in interpreting the results or in visualizing them as real contributions to progress. A mosaic becomes a design only after the individual pieces of stone and glass are fitted together. Technical committee research becomes progress when the details are fitted into an interpretive report.

One can probably think of many examples of committee detail that may have had little meaning to the outsider, but I have selected paint for my example, simply because I happen to be familiar with that field.

If you thumb through Part 4 of the 1952 Book of ASTM Standards, you will encounter 678 pages of standards and methods devoted to paint. The titles include the names of scores of pigments and other raw materials as well as common and uncommon paint properties. You may wonder how the details of these painfully evolved standards and methods are related to progress in paint technology. Is there any tie-in?

Progress in Paint Technology

For purposes of discussion, let us consider just one narrow branch of paint technology, namely, house paint. Statistics show that 8 out of every 10 houses built in the U. S. are of wood frame construction. Most of these houses depend upon exterior house paint to provide beauty and preservation. House paint, therefore, touches the lives of most of us—unless we happen to live in apartments or hotels.

At the time ASTM was founded in the early 1900's, the homeowner could buy any exterior paint he wanted, just so long as it was lead and oil. Lead and oil paint is still available, but few homes are painted with it today. Most homes are now painted with ready-mixed paint which first attained popularity about 30 years ago. Early ready-mixed house paint contained a blend of zinc oxide and white lead pigments with a small amount of inert pigment. The zinc oxide–white lead paint had certain appearance advantages over lead and oil, but cracked on prolonged exposure. Cracking creates recoating difficulties, for its necessitates removal or burning off the old paint. When titanium dioxide was introduced in the 1930's, it paved the way for major improvements in ready-mixed paint.

Titanium dioxide made possible an immediate upgrading in appearance quality. In addition to contributing opacity and whiteness, it also makes modern paint self-cleaning and durable. Self-cleaning is accomplished by controlled chalking. Chalking—the gradual sloughing of the surface layer of paint—keeps white paint bright and white and also relieves the mechanical stresses that might cause film cracking. Chalking automatically prepares the surface for the next paint job.

Accelerated Testing of Paint

ASTM has carried on intensive weather testing studies during the past 25 years. As a result, it is now possible to spell out the improvements in paint by making weather tests in conformance with standard methods.

Weather is not a constant environment. It varies from Maine to Florida and from the Gulf States to Death Valley. It varies from hour to hour and from year to year. It is only natural, therefore, that ASTM paint experts became interested in accelerated or machine testing of paint as a means of obtaining a more reproducible testing environment. A vast store of literature has been built up on accelerated paint tests.

Much time and thought have been given to the preparation of panels for weather and machine testing. Among details that have been studied are the selection of lumber for test panels, the construction of test panels and mounting racks, and the minute trifles that go into panel preparation.

The effect of weather on paint and how that effect can be evaluated have been delineated. Methods for measuring such factors as chalking, checking, cracking, erosion, flaking, and gloss changes have been evolved.

Titanium dioxide can be considered as the catalyst that started the chain reaction. The development of an industry standard for the pigment itself was the first detail. Next titanium dioxide contributed certain qualities to paint. These details had to be studied and measured. This, in turn, led to the establishment of standard weather testing practices and test panels—more details. Accelerated weather testing machines and methods were side reactions—still more details.

One standard after another has contributed to the evolution of modern ready-mixed house paint. To the casual technical reader, these isolated details might appear meaningless, but each was a stepping stone to some new fragment of knowledge.

There is an ironical twist to progress in house paint technology. As the durability of house paint has been increased, it takes longer and longer to obtain exposure results. Thus, future progress may be slower, simply because modern paint is better.

How does all this become a concern of ACR? One function of ACR is to sponsor interpretive reviews of ASTM progress in the materials field for consumption of our general membership. Will you give some thought to your own field and to ways and means of popularizing its committee work for ASTM membership as a whole?

[1] Vice-president, Pratt & Lambert, Inc., Buffalo, N. Y.; Member ASTM Administrative Committee on Research.

Microchemical Apparatus Subcommittee Organized

A NEW Subcommittee on Microchemical Apparatus has recently been organized to function as a part of Committee E-1 on Methods of Testing to carry on the standardization activities formerly handled in a Division of the American Chemical Society. The transfer of this activity to the ASTM is the result of action taken by the ACS to discontinue standardization activities, except on the subject of reagents, and to transfer such projects to groups organized for this purpose such as the ASTM.

The personnel of the new subcommittee includes the members of the ACS Committee, all of whom will serve as Special Adviser Members, as follows:

Al Steyermark, *Chairman*, Hoffman-LaRoche, Inc.
J. J. Moran, *Secretary*, Kimble Glass Co.
H. K. Alber, The Arthur H. Thomas Co.
V. A. Aluise, Experiment Station, Hercules Powder Co.
E. W. D. Huffman, Huffman Microchemical Laboratory
E. L. Jolley, Corning Glass Co.
Julius A. Kuck, Dept. of Chemistry, City College of New York
Clyde L. Ogg, Eastern Region Utilization Branch, U. S. Department of Agriculture

The personnel of the subcommittee will be enlarged to include representatives appointed by technical committees of the ASTM which have an interest in microchemical apparatus.

The ACS Committee has been very active for several years and has done excellent work in assembling specifications for much of the apparatus used in microchemical laboratories. Steps will now be taken to establish standards for the various types of apparatus.

The new committee will deal with the entire field of microchemical apparatus including glassware, metalware, filters, etc. While its scope of work may appear to overlap that of the several existing E-1 subcommittees on laboratory apparatus, microchemical apparatus is highly specialized in design as well as in size and any overlap in interest and duplication of work will be avoided by suitable cross-representation in membership. All matters pertaining to micro- and semimicro-chemical equipment would, of course, come under the immediate jurisdiction of this new committee.

It should be pointed out that the design of much microchemical apparatus is closely related to and determined by its manner of use. Eventually, it may be found necessary to undertake the standardization of microchemical methods. Some work has already been done in this direction in the field of agricultural products, and there may develop a need for extending it to other types of materials. If it should be found necessary to undertake the standardization of test methods, it may later be found desirable to establish all of this activity under a separate ASTM Technical Committee, as has been done for emission spectroscopy, chemical analysis of metals, absorption spectroscopy, and mass spectrometry.

Wires for Electrical Conductors

Statistical Sampling Procedures Standardized for Tinned, Lead-Coated, and Lead-Alloy Coated Copper Conductor Wires.

AFTER some three years of effort by Committee B-1 members and special industry advisers, the committee at its January 13, 1956 meeting accepted for letter ballot the establishment of statistical sampling procedures in ASTM Specifications B 33 and B 189. These specifications cover, respectively, tinned soft or annealed copper wire, and lead-coated and lead-alloy-coated soft copper wire, both for electrical purposes. Just five years ago, Committee B-1 on Copper Wire established the first statistical sampling procedure in an ASTM specification (Specification B 1 for Hard-Drawn Copper Wire). In 1953, Specifications B 3 for Soft or Annealed Copper Wire were revised to include the statistical basis for sampling.

Tentative Specifications for Silver-Coated Soft or Annealed Copper Wire, (B 298) first published in 1955, are under consideration for revision in 1956. This product has become increasingly important in high-temperature applications. Two new classes will be added, including wires whose silver coating amounts to $2\frac{1}{2}$ and 6.1 per cent of the total weight. Also, since bare spots are likely to occur when the silver coating is under 40 microinches in thickness, wire sizes in this category will not be listed, but a statement will be included that such sizes can be purchased if desired. In the sodium polysulfide test for determining continuity of coating, a 15-sec dip in an HCl solution will be required in order to remove silver sulfide before the specimen is examined for copper sulfide.

ASTM Specifications for ACSR Conductors (aluminum conductors, steel reinforced) (B 232) will be revised to permit steel core wire with galvanized coatings heavier than standard weight to be used. Also to be added is a second class of conductors for weather-resistant use having a lay not less than 8 nor more than 16 times the outside diameter of the conductor.

Casein

New Technical Committee Organized

AS THE result of a conference held at ASTM Headquarters, establishment of a new technical committee to develop standards in the field of casein was recommended to the Board of Directors and approved. Plans are now being laid to effect the organization of the committee.

Apparently at the present time much of the casein that is used commercially is imported. With the price of casein increasing, however, there will be more domestic production. This will no doubt mean that the importations will be more subject to testing according to American standards. Methods of grading may be established with the classification based on the degree of purity.

There are different requirements for casein according to its usage and while there is no common denominator, many properties should receive attention including strength, acid, ash, odor, color, and solubility; viscosity is of particular interest. The largest percentage of casein, is, of course, used in the paper industry but there are other uses of considerable importance such as in adhesives, paints, etc. The proposed scope of the committee reads as follows:

Definitions of terms and the study and formulation of test methods and specifications covering industrial casein.

A steering committee has been set up consisting of the following members: H. W. Shader, Armstrong Cork Co., chairman (consumer); S. B. Gilpin, Avoset Co., (producer-domestic); L. E. Clark, Perkins Glue Co., (consumer-adhesives field); Joseph Brown, Tupman-Thurlow Co., (producer-importer); and E. O. Whittier, U. S. Department of Agriculture, (general interest).

Invitations to membership have been extended. Based upon the replies, an initial personnel will be drawn up and a date set for the organization meeting. Any inquiries with respect to this new undertaking should be addressed to Society Headquarters.

Electrical and Electronics Materials in ASTM

VIRTUALLY all the materials on which standards are written in ASTM are used in one way or another in the electrical and electronics industry. The subject of this review might be misleading were it not indicated at the outset that electrical and electronics materials as discussed here are those materials which are used in this industry because of a particular electrical (or magnetic) property or combination of such properties.

There is something to be said, too, for considering the electrical and electronics industry as one industry, though there are those who would disagree and with considerable supporting evidence. While materials requirements may differ drastically when the material is used in a multi-kilowatt generator as compared with the use in a tiny radio-frequency transformer, the basic properties of the material needed for each application are the same, and the difference comes in relating these properties to service conditions. One application is concerned with low currents, the other with high currents, and who can say where the dividing line is? The two aspects of the industry blend into each other over a large undefined area, applications where the currents cannot be classified as either low or high.

So in ASTM the low-current and the high-current aspects are generally handled in the same committees, and the power engineer finds a common ground with the electronics engineer in the field of engineering materials.

Electrical and electronics materials may be classified broadly as magnetic materials, conductors, semiconductors, and dielectrics. ASTM Technical Committees concerned with electrical properties of materials fall into two distinct categories—those concerned with particular properties or use regardless of the material composition and those concerned with a basic composition or class of material and the properties required to define each material. In the former category are Committees A-6 on Magnetic Properties, D-9 on Electrical Insulating Materials, and F-1 on Materials for Electron Tubes and Semiconductor Devices. Except for the fact that the scopes are limited to metallic materials, Committees B-4 on Metallic Materials for Electrical Heating, Electrical Resistance and Electrical Contacts, and B-1 on Wires for Electrical Conductors also fall in the first category.

In the latter category are a number of committees, each having some interest in electrical materials but generally looking to one or another of the above committees to develop the electrical tests and specifications. Matters of mutual interest are often handled by liaison and joint task groups.

The Society's work on electrical materials may be conveniently considered under the four major headings—magnetic materials, conductors (including resistance materials and contacts), semiconductors, and dielectrics.

Magnetic Materials

The focal point for this work is in Committee A-6 on Magnetic Properties. This committee pioneered in the establishment of standard terminology and symbols used in consideration of magnetic materials and represents the Society (together with Committee D-9) on Sectional Committee C42 on Definitions of Terms functioning under ASA procedure. Committee A-6 has developed standards for magnetic materials used in transformers, motors, etc., and the corresponding methods of test. In cooperation with the committee concerned with electron tubes, Committee A-6 developed methods of test for feebly magnetic materials used, for example, in cathode-ray-tube shields. In the scope of Committee A-6 are also included test methods for such materials as resin-bonded powdered iron and ferrite cores used in radio frequency transformers and bi-stable ferrite cores used in various control and memory devices.

Committee B-9 on Metal Powders has a primary interest in metal powders as applied to powder metallurgy. The material is also used for resin-bonded magnetic cores for high-frequency transformers as well as in magnetic-particle nondestructive testing and, therefore, there is some interest in the magnetic properties covered by Committee A-6. Committee C-21 on Ceramic Whiteware and Similar Products, has established a project on ferrites. Since these are magnetic materials, liaison with Committee A-6 will be effected.

Conductors

Work in this area is centered mainly in two committees—Committees B-1 on Wires for Electrical Conductors and B-4 on Metallic Materials for Electrical Heating, Electrical Resistance, and Electrical Contacts although, as indicated below, other committees are concerned with materials used for conductors. All types of conductors—copper, copper-coated steel, aluminum, etc., from the smallest sizes of wire used in miniaturized components for electronics to the largest sizes for cross-country power transmission as well as bus bars used in the electro-metallurgical and electro-chemical industries—are handled by Committee B-1 in cooperation with other committees. Printed circuits based on copper-clad laminates are coming into wide use in the electronics branch of the industry. Both electrolytic and rolled foil are used in this application, and standards for these materials are developed by the above committees.

Resistance metals and alloys such as are used in electric stoves, electric furnaces, etc., are under the aegis of Committee B-4. In this committee also is centered the very active work of the Society on electrical contacts. Nonmetallic resistance materials do not have a "home" in ASTM, though there is one standard on conducting rubber developed by Committee D-11.

Committee B-5 on Copper and Copper Alloys, Cast and Wrought, Committee B-7 on Light Metals and Alloys, Cast and Wrought.—Because of the nature of the material covered, both committees have an interest in the electrical conductor field. Generally, these committees look to Committee B-1 for electrical test methods.

Semiconductors

This is a relatively new area for ASTM, having its official beginning in the organization of Committee F-1 on Materials for Electron Tubes and Semiconductor Devices at the 1955 Annual Meeting of the Society. Standardization projects are under way on germanium oxide and germanium metal which among others, find application in transistors and rectifiers. Also in progress is a program of standardization for luminescent materials used in cathode-ray tubes.

Dielectrics

Though there is wide interest in many of the technical committees in materials having dielectric properties, the electrical properties of dielectrics and electrical insulating materials, in general, are under the wing of Committee D-9 on Electrical Insulating Materials. Committee D-9 has active groups on insulating varnishes, paper, fabrics, plastics, ceramics, mica, filling compounds, and insulating oils. Because of this wide interest in a number of materials, Committee D-9 works closely with other committees concerned more with me-

chanical properties of these materials. For example, there is joint activity between Committees D-9 and C-21 on Ceramic Whiteware and Similar Products in the development of standards for piezoelectric and high-dielectric-constant ceramics.

Committee D-11 on Rubber occupies a special position with respect to dielectric materials, serving as a home for the Society's work on protective equipment for electrical workers. This group in Committee D-11 functions as Sectional Committee J-6 on this same subject. Also in Committee D-11 is centered the Society's work on insulated wire and cable, and a number of standards in this area have been developed. Both Committees D-9 and D-11 have standards on insulating tapes, the rubber-base tapes being under the jurisdiction of Committee D-11.

Committee D-9 is currently engaged in development of a specification for copper-clad laminates used in printed circuits. For the copper foil, reference will be made to standards developed by the "B" Committees mentioned above. Committee D-9 is especially concerned with the insulating part of the copper-clad laminate. A similar situation exists with regard to magnet wire on which Committee D-9 has recently established a project. Most of the effort here will be on test methods for magnet wire insulation, and representation on Sectional Committee C9 on Magnet Wire will be strengthened.

Committee C-14 on Glass and Glass Products.—Electrical grades of glass are used in textile form, in bulk and in blown form as electrical insulation and for electron tubes, light bulbs and the like. Electrical aspects of these materials are of interest in Committees D-9 and F-1.

Committee C-21 on Ceramic Whiteware and Similar Products.—Liaison is maintained with Committee D-9 where electrical properties of ceramics are of interest.

Committees D-1 on Paint, Varnish, Lacquer and Related Products, D-2 on Petroleum Products and Lubricants, D-6 on Paper and Paper Products, D-13 on Textile Materials, D-14 on Adhesives, and D-20 on Plastics.—Each of these committees is concerned primarily with properties other than electrical. The materials are all used, however, as electrical insulation, and within Committee D-9 there are subcommittees concerned with insulating properties of the above materials. Liaison between Committee D-9 and the above committees is maintained where necessary.

General Considerations

Only brief mention has been made above of the Society's longtime interest in materials for electron tubes, now centered in Committee F-1. Difficult problems, particularly in materials for electron-tube cathodes, have been met and solved by this group, and their efforts in no small measure have contributed to the reliability of mass-produced electron tubes for radio, television and electronics generally. The semiconductor work mentioned above is also centered in this committee.

Electrical properties of materials as discussed above are of interest from the point of view of application of materials in the electrical and electronics industry. Electrical and magnetic properties are also used in ASTM in another important way—as a tool for analysis and testing. For some time, magnetic powder has been used as a basis for nondestructive testing of steel castings and forgings. Electrical resistance and loss are both used as a means of determining moisture content of various materials. Electrical conductivity of various flooring materials and floor waxes is an important consideration from the point of view of reducing static spark danger in hazardous locations.

Ultrasonic pulse techniques for measuring the elastic constants of materials depend on electrical equipment for generating and detecting the pulses.

Many other examples could be given. Suffice it to say that ASTM has very broad interest and coverage of the electrical field.

Tinius Olsen—75 Years of Testing

One of the pioneering testing machine companies in this country recently celebrated its 75th anniversary. The Tinius Olsen Testing Machine Co. was founded in 1880 by Tinius Olsen a native of Norway. Soon after coming to this country, he devoted himself to the design of testing machines and in 1880 struck out for himself, designing and patenting the "little giant," the first "universal testing machine."

Tinius Olsen was one of the founding members of the ASTM when it was organized in 1898 as the American Committee of the International Association for Testing Materials.

The company has supported the Society through the years and at the present time Tinius Olsen II is a Vice-Chairman of the Philadelphia District Council. The accompanying photograph shows three generations of Olsen leadership. Tinius Olsen II (right), president of the company, and left, his father, Thorsten Y. Olsen, chairman of the board. The portrait is that of Tinius Olsen.

Work of Panel—Joint Committee on Effect of Temperature, Provides Important Data and Publications

By G. V. Smith,[1] Chairman

THE NEED to gather data relating to specific fields of interest into useful compilations is widely recognized. In the field of use of metals in service at elevated temperatures, such need was especially great in the mid-1930's. Interest in using metal under creep conditions had been increasing, but creep tests were (and still are) very time-consuming, and relatively few laboratories could perform such tests—hence, a desire to share and compare results.

The ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals recognized the need for compiling creep data and undertook a survey to gather and evaluate available data. Their efforts culminated in the publication in 1938 of "Compilation of Available High-Temperature Creep Characteristics of Metals and Alloys," a widely used and appreciated volume.

Another important service was performed by the Joint Committee in 1940 in conducting a survey of the equipment available in this country for testing at elevated temperatures. The results of this survey were of great help during the subsequent war years to Government agencies in setting up correlated research programs on materials for service at elevated temperatures.

Since the publication of the 1938 volume, industry, as well as Government agencies, and universities, have looked to the Joint Committee as an agency for the compilation and evaluation of data on the effect of temperature on metals. Consequently, after the end of the late war, which brought with it an intensified interest in the effects of temperature on metals, the Joint Committee, through the medium of its Data and Publications Panel, began a series of surveys, the first involving a resurvey of the greatly expanded testing facilities, including both low- and high-temperature equipment, with subsequent surveys concerned with compiling test data. A number of the surveys have now been published, and others are still under way.

Because of the greatly expanded interest in metals at elevated temperatures and the great quantities of data becoming available, it seemed unwise to attempt to survey all materials simultaneously. Rather, the decision was taken to survey in turn specific groups of materials; the first of these, because the need seemed most pressing, was the austenitic stainless steels. Subsequent surveys have dealt with most of the other metals of commercial interest.

Fortunately, during the interim of conducting the several surveys and evaluating the results, a compilation of data on wrought ferrous materials carried out by J. J. Heger and R. F. Miller for U. S. Steel Corp., was made available to the Panel and under its auspices was published by ASTM.

Surveys Published by ASTM

The surveys completed to date, all published by the American Society for Testing Materials in its *Proceedings* or in its Special Technical Publication Series (*STP*) are as follows:

High-Temperature and Low-Temperature Testing Equipment in the United States—*Proceedings*, Am. Soc. Testing Mats., Vol. 49, p. 249 (1949).

Report on the Strength of Wrought Steels at Elevated Temperatures prepared by J. J. Heger and R. F. Miller, *STP No. 100*, Am. Soc. Testing Mats. (1950).

Report on the Elevated-Temperature Properties of Stainless Steels—prepared by W. F. Simmons and H. C. Cross, *STP No. 124*, Am. Soc. Testing Mats. (1952).

Report on the Elevated Temperature Properties of Chromium-Molybdenum Steels—prepared by W. F. Simmons and H. C. Cross, *STP No. 151*, Am. Soc. Testing Mats. (1953).

Report on the Elevated-Temperature Properties of Selected Super-Strength Alloys—prepared by W. F. Simmons and H. C. Cross, *STP No. 160*, Am. Soc. Testing Mats. (1954).

Elevated Temperature Properties of Carbon Steels—prepared by W. F. Simmons and H. C. Cross, *STP No. 180*, Am. Soc. Testing Mats. (1955).

Elevated Temperature Properties of Copper-Base Alloys—prepared by C. Upthegrove, *STP No. 181*, Am. Soc. Testing Mats. (1956).

The surveys currently under way are listed below, with publication expected over the next one to two years:

Relaxation Properties of Steels and Super-Strength Alloys at Elevated Temperatures

Strength of Medium Carbon Steels

Strength of High-Chromium Steels

(*Please turn page*)

THE WORK of the Joint ASTM-ASME Committee on Effect of Temperature on the Properties of Metals has been outstanding down through the years. There are many facets to the work of the committee. One, for example, is the financing and sponsoring of important research work in various laboratories to give us new knowledge on metals for use at high and low temperatures. One of the most significant and perhaps the most far-reaching phases of this committee's work is the gathering and publication of data on the high-temperature and low-temperature properties of metals. We were impressed at the committee meetings during the ASME Chicago Anniversary by just how much work the Data and Publications Panel had done and was carrying out. We felt a résumé of this work and a list of the publications would not only be of widespread interest to all those concerned, but that as an example of effective cooperation by leading companies and technical men it would be of interest to many in other fields as well. Consequently, this led to the accompanying article prepared at our suggestion by Professor Smith, Chairman of the Panel responsible for the work.

Perhaps the tone of this article is significant, too, it is a simple, straightforward statement, not heralding the work, but telling simply what has been done, what is scheduled, and a bit on how it is done. It takes some restraint for us not to praise this activity too highly. It is of great significance and unquestioned value, but also we are reminded it is one of many cooperative activities which go on constantly not only in ASTM, but in other engineering and technical societies.

Perhaps because of the nature of our work in which the Consumer and Producer and General Interest cooperate constructively in both research and standards, such methods of getting valuable results are more frequently in evidence in ASTM.

[1] Professor of metallurgical engineering, College of Engineering, Cornell University, Ithaca, N. Y.

Strength of Weldments
Strength of Aluminum and Magnesium Alloys
Physical Properties at Low and High Temperatures
Test Facilities within the United States

Most of the data surveys have dealt with mechanical properties at elevated temperatures, as the foregoing titles indicate. An exception is the "Survey of Physical Properties at Low and High Temperatures" which is undertaking to gather information concerning such properties as thermal conductivity, thermal expansivity, magnetic and electrical characteristics, etc., at both low and high temperatures.

Operating Methods

The methods of operation of the Data and Publications Panel in conducting the surveys may be of interest. For each survey, a small test group comprising generally, but not always, members of the Panel is appointed. This task group prepares an appropriate data form, which, after approval by the Panel, is sent to all laboratories that possibly might have original data. The task group receives the data that are contributed and arranges with experts on the subject matter for the evaluation of the results and the preparation of a manuscript suitable for publication. This manuscript is reviewed by the task group and by the Panel Chairman, and revised if necessary.

The costs of evaluation and manuscript preparation are borne by the Joint Committee from funds solicited from industry. The costs of publication are borne by the ASTM, which charges a nominal price for the completed product to defray, at least in part the costs of publication and distribution.

Continuing Compilation Proposed

As the Panel approaches the completion of its current series of data surveys, it proposes to direct its efforts away from periodic surveys, and instead to compile data on a current and continuing basis. Data forms have been prepared which, it is hoped, will be as acceptable to cooperating laboratories as to the Data and Publications Panel, and hence, as data are obtained and recorded, a copy can be made for the Panel. On release of the data by the testing laboratories, the data will be forwarded to the Panel, which will compile and summarize the data on a continuing basis, and issue summary reports at suitable intervals.

The record of accomplishment of the Panel is a tribute to the interest in its activities and to the active cooperation of testing laboratories throughout the country, as well as of the members of the Panel.

Members of the Data and Publications Panel are:

H. L. Burghoff, Chase Brass Co.
C. L. Clark, Timken Roller Bearing Co.
H. C. Cross, Battelle Memorial Institute
R. M. Curran, General Electric Co.
C. T. Evans, Jr., Universal Cyclops Steel Corp.
F. B. Foley, International Nickel Co.
J. W. Freeman, University of Michigan
G. J. Guarnieri, Thompson Products
W. L. Havekotte, Firth Stirling Inc.
A. J. Herzig, Climax Molybdenum Co.
J. J. Kanter, Grane Co.
Sidney Low, Chapman Valve Manufacturing Co.
V. T. Malcolm, Chapman Valve Manufacturing Co.
D. L. Newhouse, General Electric Co.
E. E. Reynolds, Allegheny Ludlum Steel Corp.
E. L. Robinson, consultant
Leo Schapiro, Douglas Aircraft Co., Inc.
W. F. Simmons, Battelle Memorial Inst.
G. V. Smith, Cornell University
John S. Worth, Bethlehem Steel Co., Inc.
R. D. Wylie, Babcock and Wilcox Co.

AIChE Discusses the Value of Technical Society Participation

"The Technical Society—Its Place and Value in Industry" was the title of the fourth session of the Annual Meeting of the American Institute of Chemical Engineers, held in Detroit on November 29.

In his paper, "Should Industry Encourage Technical Society Membership?" G. L. Royer, American Cyanamid Co., pointed out that in industry today increasing emphasis is being placed on professional development, and membership in professional organizations is a key step in this development. The participation of these men as lecturers, listeners, committee members, and leaders in the various societies has a broadening effect resulting from contact with other members of the profession. This is particularly important during the current shortage of engineering manpower, because industry finds it necessary to delegate greater responsibility to its younger men than ever before. The company that can accelerate the professional growth of its engineers, Mr. Royer concluded, has a definite edge on its competititors.

"The Importance of a Technical Literature" was considered by John J. McKetta, Jr., of the University of Texas, and the extent to which industry should encourage its employees to publish technical papers. Mr. McKetta's conclusions were that (1) there is a moral responsibility to repay in kind the information and ideas obtained from the published work of others; (2) well-written papers by staff men bring recognition to the company; (3) the prestige afforded the author-employee is his just due as a professional; and (4) technological progress depends on the efficient use of engineering and scientific manpower and wasteful duplication of technical work cannot be tolerated.

Adolph Monsaroff, Monsanto Canada, Ltd., discussing the "Advantages of Society Participation to the Company," stated that association with senior professional persons may be the most valuable factor in the professional development of younger employees. The attainment of important offices in professional societies by higher ranking employees enhances the prestige of the company. Recognition of a member by a technical society is equally a recognition of his company. Participation of this kind fosters a healthy and progressive spirit among the staff and the company generally stands to gain more than it gives. Younger staff members are usually the ones who need a push in this direction, and are the ones who probably derive the most benefit in developing a truly professional attitude. Management personnel bring to the technical society the maturity and eminence that offer inspiration to younger members.

Electronic Components Symposium to Feature Present Accomplishments, Future Trends in Parts Field

A COMPREHENSIVE review of accomplishments in the electronic components field and a survey of future trends will highlight the "1956 Electronic Components Symposium" which is scheduled to be held in the Department of Interior Auditorium, Washington, D. C., May 1 to 3. This is the seventh in a series of annual technical meetings devoted to electronic components.

Sponsored by the American Institute of Electrical Engineers, The Institute of Radio Engineers, the Radio-Electronics-Television Manufacturers Assn., and the West Coast Electronic Manufacturers Assn. with the active participation of the Department of Defense and the National Bureau of Standards, the three-day program will be divided into seven sessions, including an evening session devoted to electron tubes and solid state devices:

1st Session—Opening
2nd Session—Progress with Materials
3rd Session—Theory and Operating Principles
4th Session—Instrumentation and Measurements
5th Session—Electron Tubes and Solid State Devices (Evening)
6th Session—Passive Components I
7th Session—Passive Components II

Random Samples...

FROM THE CURRENT MATERIALS NEWS

From the broad stream of current materials information flowing from "in-box" to "out-box" in a busy editorial office, random samples (mostly random) have been plucked. Thinking them worth re-showing to ASTM'ers who may have missed the original articles, we have included them here. Of course, we had to trim the samples to fit. There will be those who are not satisfied with samples, especially ones which are not really random. But these ASTM'ers can contact the institution, magazine, governmental agency, etc., who placed the original information in the stream, or address Random Samples, ASTM, 1916 Race St., Philadelphia 3, Pa.

What an Appetite!

AFTER several years of searching for a way to stop pileated woodpeckers from turning solid poles into useless shells, utility companies are no closer to a solution now than they were to start with, but they are more determined than ever to find one.[1] The pursuit of an effective repellent has now become a matter of utmost urgency.

This year pileated woodpeckers will damage almost 3 million utility poles, pile up losses estimated at "many millions" of dollars. In drilling for food, excavating for nest sites, or for other reasons still undetermined, the bird makes no distinction between trees and utility poles. Actually, no one knows for sure why the birds do attack poles.[2]

But once they start on a pole, the birds generally do not stop until the pole starts swaying under the weight of its power lines. More than once, a single pileated woodpecker hard at work has carved out a cavity 5 in. across and almost 1 ft into the center, left over a bushel of sawdust in its wake. To make matters more difficult, the pileated woodpeckers, protected by conservation laws, have been increasing in number. Varieties of the bird now occur throughout the United States and Canada, causing destruction wherever they range. Nor are their depredations limited to utility poles. To a lesser degree, the birds also attack buildings, valuable shade trees, and various other wooden and sheet metal structures; but the birds' predilection for nest sites at least 20 ft (and preferably much higher) above ground saves these smaller objects from widespread attacks.

There's a $12-million a year purse waiting for anyone able to stop the raiders. This is the price Penn State's Richard Jorgensen believes utility companies would pay—and quickly—for permanent protection. Here is how he figures it: Out of 12 million poles used each year, an estimated 3 million are particularly vulnerable to attack because of location in heavily wooded sections—the natural habitat of the birds. Utility companies now pay $3 to 5 per pole for preservation, would gladly spend an equal amount on an effective repellent for the 3 million vulnerable poles.

The obvious answer to this problem—systematic extermination of the marauding species—is out. An appetite for tree-destroying insects has made the pileated woodpecker a pet of the forest conservationists, safeguarded by Federal and state laws.

Meanwhile, the birds continue carving up poles, defeating one attempt after the other at stopping them. Here are just a few of the hurdles already cleared by the birds:

Some companies lashed holed sections of old poles to the top of replacement poles, others simply left old poles next to new poles. In both cases, for reasons known only to them, the woodpeckers ignored the old poles and attacked the new ones.

A few firms attached red flannel streamers, metal strips, or metal flashers to the poles. The birds held off only long enough to make sure the gimmicks were harmless.

Some companies wrapped poles, except for the top 8 ft, with 19-gage, ½-in.-mesh hardware cloth. Woodpeckers tore through the material; in some cases, they even chiseled out hardening compounds used to plug old holes and reinforce the poles. Use of poles made from imported, very hard, oily wood also proved ineffective.

As a result, the search for an effective repellent has turned to chemical companies. A number of compounds have already been tried; none has yet proved effective.

Right from the beginning, fully creosoted poles fell under attack by the miscreants. Other coal-tar-based formulations have similarly failed to deter the birds. One power company tried (unsuccessfully) spraying the poles first with a 5 per cent solution of pentachlorophenol in a light petroleum solvent, then painting them with formaldehyde and a nonhardening compound with a bituminous base and a medicated odor. Another compound based on a trinitrobenzeneaniline complex, a rabbit repellent, also proved useless. (Penn State's captive woodpecker sat on the brush being used to paint test poles with the complex.)

Other formulations using alkalies to give the birds harmless "hot foots" have also failed. Nonetheless, the chemical line of attack still seems the most promising, says Jorgensen, and there are several new repellents now undergoing or ready for test runs. Of these, nicotine sulfate, successfully repelled pigeons and sparrows and will soon be tried on the woodpecker. Another, Roost-No-More (National Bird Control Laboratories, Skokie, Ill.), has effectively deterred pigeons and starlings from settling on public buildings, is now being tested against woodpeckers on Gulf States Utilities poles in Beaumont, Tex.

From findings so far, it seems that the pileated woodpecker is not ordinarily repelled by smell or taste, that for any chemical repellent to prove successful, it will have to be much stronger than creosote or any of the other compounds tested to date. In addition, the ideal chemical repellent will include, among others, these characteristics: *Safety.*—It must in no way injure the pileated woodpeckers. *Easy application.*—It must lend itself to painting or spraying since these are the only practical methods of treating poles already in place. For new poles, the repellent should be miscible with standard preservatives, able to be applied at the same time as the preservatives. *Durability.*—Poles must last for 30 years, and a repellent should —ideally—remain effective for the life of the pole. (Repellents that last for a shorter period but are inexpensive and easily applied should not be counted out.) *Cost.*—An effective repellent

[1] Many varieties of woodpeckers wreak havoc on utility poles, but the particular type known as the pileated woodpecker leads the assault, far overshadows the others in the extent of its depredations.

[2] Finding out is the first objective of a research project recently established by a grant from four power companies at the Pennsylvania State University School of Forestry. The second objective will be the way to stop them.

meeting all these requirements, Jorgensen figures, could bring (including application) as high as $5 per pole.

Any company that thinks it has a compound that will do the job should contact Richard Jorgensen, Pennsylvania State University, School of Forestry, University Park, Pa.

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Packaged Entertainment

A MAJOR advance in the automotive radio field has been revealed by the Delco Radio Division of General Motors in Kokomo, Ind.—the introduction of an automobile radio which now includes transistors. The new radio will be available for the first time on a production car in the Chevrolet Corvette for this year.

General Motors thus becomes the first to go into production with automotive radios with transistors, immediately available in cars.

The greatly advanced radio which the Chevrolet Corvette will have is one in which the spectacular transistor replaces vacuum tubes in the output stage of the receiver and the vibrator in the power supply.

These Delco "Hi-Power" transistors, developed in Delco Radio's electronics laboratory, provide this new radio with one third more power, less distortion, a wider tonal range, greater reliability, elimination of vibrator buzz, and lowered current drain. It also points the way toward smaller and lighter radios to permit better instrument panel styling.

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Aluminum on Wheels

THE average 1956 model American passenger car became lighter as a result of an increase in the use of aluminum. The increase was revealed in a special survey report by Aluminum Company of America.

Aluminum usage in the average auto has climbed from 29.6 lb in 1955 cars to 35.2 lb in '56 models. Thus the survey indicates a record-breaking 246-million lb of the light metal will be used in 1956 passenger cars this year if these are produced at an estimated annual rate of 7 million cars.

In reporting on the extensive survey, Harry L. Smith, Jr., vice-president of sales development and market research for Alcoa stated that an important part of the increase appears as attractive aluminum exterior trim—some of it in color.

All of the aluminum used reflects a savings in car weight, since it weighs only one third as much as most metals.

Looking ahead, studies by Alcoa specialists indicate aluminum applications on autos will rise to 49.8 lb by 1960, and to 81 lb by 1965. If aluminum were applied to all automotive parts which can be converted to its use, the total on each car would top 300 lb.

The growing automotive market is one of the factors which in 1955 moved aluminum to a production rate second only to steel. The Alcoa survey shows that close to 50 per cent of the aluminum in passenger cars goes into automatic transmissions. Another major application of the metal is in the engine, now utilizing 30 per cent of the total. Body trim accounts for another 7 per cent, and offers one of the most promising applications for future growth. The balance of the aluminum goes into miscellaneous applications such as wiring, brakes, power steering, and air conditioning units. In interpreting the survey several reasons were given for the increased application of aluminum. The trend to V-8 engines was important since they require more of the light metal than six cylinder units. Another factor was the General Motors' change in automatic transmission design, requiring an additional 14 lb of aluminum per unit.

Aluminum in trim likewise advanced with Cadillac and DeSoto using aluminum grilles, and with Packard and Plymouth featuring large grille components.

Growing applications of aluminum die castings and impact extrusions to auto parts added to the increase. Die casting, the survey revealed, was the principal production method for aluminum auto parts. New models average 15.7 lb of aluminum die castings per car as compared to 12.3 lb in '55 models.

Total aluminum consumed for passenger cars would be even higher than the 246-million lb total if aluminum replacement parts and auxiliary uses were included. Replacement parts will consume an average of 5 lb of aluminum per car during its life. An average of 2 lb of the light metal is consumed for deoxidizing the steel for each car. Over 1 lb is employed as an alloying ingredient for the zinc die castings. One of the popular new upholstering fabrics used 0.8 lb of aluminum foil thread in its weave.

The next important advance for aluminum in automobiles is predicted as aluminum radiator fins joined to brass tubing. Eventually, auto radiators may well be all aluminum. Engine blocks and heads offer excellent possibilities as do engine drums and differential housings.

Relief for Hot Pipes

NEW relief for "hot pipes" on aircraft and automobile exhaust systems has been announced. It is an aluminum-silicone paint, which fights the accelerated corrosion peculiar to engine exhaust stacks by refusing to burn off under blasting heat.

Called Alumicone by its producers, Atech, Inc., of Toledo, Ohio, the paint will withstand temperatures in excess of 1500 F, according to the manufacturer. Based on a silicone-alkyd resin base and containing aluminum pigments supplied by the Aluminum Company of America, the paint is now being used by both airlines and individual plane owners to increase the life-expectancy of aircraft exhaust systems. Where normal paint films have failed after a few hours flying time, Alumicone has remained in perfect condition after more than 400 hr in the air.

For use wherever high temperatures deteriorate normal paint films, the paint can be sprayed or brushed directly onto the metal. No special primers or involved equipment is needed. Alumicone offers not only attractive and economical protection for airplane exhaust stacks, but assures safer and longer performance life.

Although initially developed for aircraft application, Alumicone is also practicable for a variety of uses. According to Atech, Alumicone has exceptional durability on diesel mufflers and automobile and truck engines. It is also excellent for use on furnaces, stove or heater doors and parts, and for high-temperature smoke stacks.

Additional information can be obtained by writing the producer, Atech, Inc., 3800 Lagrange St., Toledo, Ohio.

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Riding on Air

DEVELOPMENT of air ride suspension for GMC trucks, which will introduce a new era of economy and efficiency in the trucking industry, was announced recently by Philip J. Monaghan, vice-president of General Motors and general manager of the GMC Truck and Coach Division.

The revolutionary new type of suspension, whereby air-filled rubberized bellows replace the conventional metal leaf springs, is now on an experimental GMC truck-trailer combination and will be ready for production late this year.

Over 400 million miles of operating experience with air suspension on GM coaches, and tests with air-rise trucks at the General Motors Proving Ground, shows that the truck air suspension

eliminates spring lubrication, repairs and replacement; either fully or partially loaded, provides smoother ride for driver, resulting in less fatigue, an important safety factor; absorbs vibration and road shocks, reducing breakage of fragile cargo; permits lighter-weight less-expensive packaging of goods for shipment; increases trailer payload capacity by lowering floor height; facilitates loading and unloading by keeping floor at constant height; encourages standardization of loading dock heights by assuring constant truck-trailer floor height; prolongs chassis life and reduces over-all maintainence; prolongs body life by lessening road shocks, reducing maintainence costs; gives better load distribution by keeping floor level; eliminates spring noise and other vibration noise; permits greater traction when needed under the driving axle of tandem-axle combinations using a "dead" pusher or trailing axle, by providing easy adjustment of air spring pressure to throw more load weight on the driving axle.

●

PVC—Another Engineering Material

In the period since the Second World War a number of promising new materials of construction have been made available to American industry. These materials are widely varied in their compositions and properties, thus affording design and fabrication opportunities of considerable scope.

One of the more interesting of these new products is polyvinyl chloride. Actually, polyvinyl chloride is not "new" in the literal sense of the word, for it has been used commercially in this country since the mid-thirties in a host of industrial and consumer products. Its application as a material of construction, while relatively "new" in this country, has been widely practiced in Europe, notably in Germany where installations made 15 to 20 years ago are still in use today. The industrial development of PVC as a material of construction in Europe was necessarily rapid because of the shortage of special steel alloys and other vital materials during a war economy. No such necessity existed in this country and accordingly, its development here has been somewhat slower. Following the war, some effort was made by European manufacturers to export PVC construction materials into the USA, but supplies and distributors were limited and not conducive to the wide-scale acceptance of the product.

In recent years, domestic resin manufacturers have devoted much research and development effort to PVC as a material of construction. As a result of this work domestically produced, high-quality PVC construction materials are currently available in this country in a variety of forms unmatched elsewhere. The properties of these materials are such as to be of interest to all industrial fabricators.

PVC is a completely synthetic material, the basic raw material for which is vinyl chloride gas, petroleum, and chlorine. This gas is converted to a fine white powder by a process called polymerization, and this powder is combined with small percentages of other chemicals to improve its processing and physical properties. It is then hot processed into various semi-finished shapes such as sheet, pipe, and fittings. The techniques of converting the raw material into these and other specialized shapes needed by the industrial fabricator are highly advanced and product availability is excellent.

The outstanding property of PVC is its resistance to corrosion. It will successfully handle most acids, alkalies, and salts in a variety of combinations and concentrations. Its physical and thermal characteristics are good and its electrical properties outstanding. It is self-extinguishing and for most applications can be regarded as free from odor, taste, and toxicity. It is light in weight, has a low thermal conductivity, and can be produced in a variety of colors and degrees of translucency. In spite of its many outstanding properties, PVC is not a "wonder material" which will cure all of the problems which confront the fabricator. Its major limitation is its tendency to soften and lose strength on heating. This behavior is reversible however, and thus forms the basis for ease of fabrication of the material. PVC can be softened by heat and formed into very complex shapes which it will retain upon cooling. It can also be welded by using the so-called "hot gas welding" method and machined and worked on conventional sheet metal and wood working equipment. Its fabrication into ducts, hoods, towers, and complex structures is readily accomplished. It can be fabricated into sleeve or bonded liners for very large tanks and structures by using specialized sandwich construction of the material. In short, PVC is a good, practical material from the fabricator's standpoint.

Correction

The January issue of the Bulletin erred in listing the Steel Founders' Society meeting as March 15 and 16. The correct dates are March 19 and 20.

ISO Draft Recommendations for Turpentine

The U. S. is a participating member of ISO 35 on raw materials for paints, varnishes and similar products, the Secretariat being held by The Netherlands. In a recent communication from the adhering body for the U. S. (American Standards Assn.) to the Secretariat, with respect to combined or separate draft recommendations for various kinds of turpentine, the following was expressed:

We in the United States are in general accord that the term "spirits of turpentine," or as it is termed in French, "Essence de terebenthine" is not limited to the oil distilled from the oleoresin collected from living pine trees, the source of gum spirits of turpentine. . . . The stump of a tree after it is cut down and weathers, increases its content of the constituents of oleoresin to a greater extent than was present even in the living tree. While the stump oleoresin contains components in addition to those of the living tree (namely, pinenes and resin acids) nevertheless it is an oleoresin, and therefore would be a form of "turpentine."

. . . Present-day practice is to extract all of the soluble components from the finely ground wood with hot gasoline or naphtha and thereafter recover the products (wood turpentine, and resin acids or wood rosin) from the extraction by steam distillation and refraction. . . .

The Federal Specifications for Spirits of Turpentine, now undergoing revision, will combine in one specification the requirements for four kinds of turpentine, which include gum turpentine, steam distilled wood turpentine, sulfate wood turpentine, and destructively distilled wood turpentine. The composition of the first three kinds is essentially alike, and the difference lies almost entirely in the odor, which for the various kinds of turpentine is due to the presence of minute quantities of esters or other odoriferous compounds. . . . Such odor causing components have no effect on the properties generally covered by the specification. This explains why a single specification for the three kinds has been established both in the ASTM and by the Federal Government.

The turpentine recovered from the products of the destructive distillation of the wood contains hydrocarbons, other than alpha and beta-pinene, but to handle this difference we merely need to set up a somewhat different set of numerical limits for the tests applied to this kind of turpentine.

The precedents referred to herein as established by the ASTM and by the Federal Government are, in our opinion, ample reason why this course should be followed in the ISO. Consequently, we must vote in favor of combining the various kinds of turpentine into one ISO Draft Recommendation rather than to have separate specifications.

The Legal Implications of Standardization

By Ralstone R. Irvine[1]

THE LEGAL consequences of standardization are, in the United States, mainly those which flow from the application of the Sherman Law. This basic law forbids only such contracts or combinations as "by reason of intent, or the inherent nature of the contemplated acts, prejudice the public interests by unduly restricting competition or unduly obstructing the course of trade."[2]

No Federal court has ever held standardization as such to be illegal under the antitrust laws. On the contrary, standardization frequently has been commended by the courts and the Federal Trade Commission.[3] The Supreme Court of the United States has described standardization as an activity "admittedly beneficial to the industry and to consumers."[4]

Like other lawful activities, standardization may be used to impose restraints and to promote monopolies. Like a lawful patent, a standard is clearly an instrumentality that may be employed in aid of a price-fixing conspiracy or to handicap a competitor who is unable or unwilling to conform to its requirements. But such unlawful restraints are not inherent in standardization.

The object of the antitrust laws is to assure free and fair competition. An analysis of the nature and effect of standardization will demonstrate that standardization, properly pursued, promotes rather than restrains competition, and most legal implications arise not from standardization but from activities which are separate and different from standardization.

Nature of Standardization

The term "standardization" has been used to cover a multitude of different activities. Let me start, therefore, by stating what I think standardization is. I consider that a standard is simply a definition of a product or procedure in terms of certain features. Standardization, accordingly, is simply the process of reaching agreement on the form and content of such a definition. It is not an agreement to do anything. Thus, the adoption of a standard, though of course it is meant for use, does not imply any particular use by anybody.

Obviously, therefore, an agreement to employ standardization as a means to carry out a price-fixing conspiracy is not standardization. Similarly, an agreement among dominant producers or purchasers to manufacture or purchase only in accordance with a standard might curtail production or boycott suppliers, but such an agreement is not standardization. It may be urged that this distinction is not very realistic: that those who participate in standardization are not engaged in an abstract exercise. Each participant wants a standard that he can use, and each believes that other participants are motivated by similar desires. If, then, each uses the standard, may not an agreement to adhere be inferred from the mere process of adopting the standard under such circumstances?

Whether such an inference is valid may depend upon the extent to which the standard serves the need of more than a single economic group. If it benefits producers and consumers alike, it will readily find acceptance quite apart from any agreement. The mere fact of general acceptance under such circumstances is not evidence of a conspiracy or combination, and the adoption of the standard is clearly legal. If, on the other hand, a particular standard appears to be in the interest only of the group promulgating the standard and is contrary to the interests of other groups, then its exclusive or preferred use might be difficult to explain except as the result of a joint effort to impose the will of one group upon the other. Undoubtedly the courts will view with suspicion any persistent adherence to standards which attempt to define terms of sale, the nature of guarantees and other matters which normally fall in the area of bargaining between buyer and seller. It is because of this danger that many standardization bodies avoid the development of such purely commercial standards.

Competitive Effects of Standardization:

Though standardization involves no agreement to use the standards created, standards are a joint creation and their probable economic effects must be recognized. The fact that a standard may be beneficial to more than one group and thereby obtains acceptance does not remove the possibility of injury to some members of the benefited groups or to some third party.

Consumer acceptance of a standard concentrates supply and demand in the standardized form and gives it a preferred commercial status. Admittedly, the prestige of a standard put forth by a recognized standards-making body may produce almost immediate wide acceptance. Will those who prefer a nonstandard form be penalized? What of those who may find it impossible or difficult to supply the standard article? What of the price differential which is likely to result, entirely apart from agreement, between the standard and the nonstandard article? In short, does not standardization automatically restrain trade in the nonstandard? The answer seems twofold:

First: In many instances the preferred position of the standard article may represent an increase of trade in it rather than a decrease in trade in nonstandard forms. This increase might bring about a reduction in the cost of the standard article owing to economies in production and distribution. If the increased sales with resultant savings in cost of a standard article result from consumer preference over the nonstandard there can be no question of legality, and this is true even though the sales of nonstandard articles have declined.

Second: Any adverse effect on trade in the nonstandard article will ordinarily be outweighed by the over-all increase in competition which results from having a standard. Let me be specific:

Broadening of sources of supply is one of the major effects of the acceptance of

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MR. IRVINE'S PAPER was presented at the Sixth Annual Conference on Standards sponsored by the American Standards Association and the National Bureau of Standards in Washington, D. C., October 26, 1955. Copies of the Proceedings of this Conference on Government-Industry Cooperation in Standardization are now available and can be obtained from the ASA, 70 E. 45th St., New York City, for $3.

[1] Donovan, Leisure, Newton, and Irvine, New York, N. Y.

[2] *Nash versus United States*, 229 U. S. 373, 376.

[3] See for example: *Maple Flooring Association versus United States*, 268 U.S. 563 (1925); *Tag Manufacturers Institute, et al. versus Federal Trade Commission*, 174 F. 2d, 452 (1949); *The Matter of Crouse-Hinds Company*, FTC Dkt 4610.

[4] *Maple Flooring Association versus United States, supra.*

standards upon competition. This permits more producers, particularly the smaller ones, to enter the market. An example will demonstrate this fact.

Formerly, there were no widely accepted standards for the valves used for pipe lines. The result was that a pipe line had to be designed for one particular type of valve, thus limiting the number of producers from whom valves could be obtained. When replacements were needed only certain manufacturers could effectively compete for this business since the other producers could manufacture the particular type of valve only by incurring the additional expense involved in handling a special order. Standards for the dimensions of such valves have now been established so that a pipe-line company has a great many competing sources of supply from which it can secure valves that will fit its needs.

Another marked economic consequence of standardization is to lessen the effectiveness of imaginary product differentiation as a price-raising device. Producers of many products which are completely or substantially identical describe them in many varied terms so that the purchaser cannot effectively compare them, discover that they are identical, and accept the lowest price. Where standards are accepted, quality and price determine the customer's choice, rather than the color and design of the label. Competition is not eliminated but instead quality competition and price competition are encouraged while price-raising competition and ballyhoo are made less profitable.

Standardization has been criticized because, under some circumstances, it may tend to produce similarity or identity of price. Does such price behavior flow from competition or does it evidence a conspiracy? One of the consequences of standardization may be similarity of product, both in design and performance. This usually results when standards are designed for products for identical operation or performance. Whenever competing articles, whether standard or not, are recognized by the consuming public as performing identical functions, sales in a given market on a given day will go to the seller offering the lowest price. Competing sellers will be forced to meet this price if they are to stay in the market. Thus, there results identity of selling prices. But similarity or even identity of price resulting from consumer acceptance of the fact that the goods offered are identical in operation and performance results normally from competition and does not evidence a conspiracy.

Function of Standards

Any discussion of the legal aspects of standardization requires that we look at some of the more important functions of standards.

Standards of Terminology:

The most basic of standards are those dealing with terminology, nomenclature, symbolization, and methods of measurement. By providing a common language, they prevent misunderstanding and lay the groundwork for further progress in standardization. Standards of this kind are not ordinarily of particular antitrust significance, and in this area an agreement to adhere may be unobjectionable. For example, a color code for identifying the chemical composition of arc-welding electrodes might be useless unless all makes are coded in the same way.

Certain possibilities of injury should not be overlooked even here, however. The displacement of old terminology or symbols may cause temporary inconvenience or hardship to some. Where definitions cover a series of grades or sizes, they should comprehend the entire range in use, or the effect might be to discriminate against wanted items. A system of identification by color or symbols should be capable of accommodating all products of the same class.

Standards of Quality:

Standards of quality are intended to assure consumer satisfaction with a product. It is hardly necessary to add that they refer only to the minimum required for compliance with the standard. The placing of a limitation on performance, except where it insures safety or aids some other function, could serve no legitimate purpose and would act as a brake on competition.

The definition of quality is essentially a statement of fitness for use.

The engineering process of formulating criteria of fitness is often a difficult and lengthy one, which may involve extensive research and result in the establishment of elaborate testing procedures. The process may lead to an increase in knowledge of the capabilities of a product, as well as to clarification in the statement of them, and the publication and use of the standard will diffuse the knowledge so gained among consumers and others interested in the product.

The education of consumers in the understanding of a product is a potent means of increasing competition through widening of the market. A standard of quality, by assuring that different makes will be equally satisfactory in important functional respects, tends to destroy the monopolistic effects of brand names, giving the consumer wider choice among suppliers.

The existence of a quality standard also provides greater opportunity for newcomers to enter the field, especially small business. It furnishes the newcomer with a guide to the minimum conditions he must meet in order to have a product that will prove acceptable. Having met these conditions, he will benefit from a market created by the standard and will be less at the mercy of established reputation and expensively advertised trademarks.

The increase in the possibility of price competition through the dissipation of fanciful advantages associated with a brand name does not mean that there will be a correlative decrease in competition by legitimate differentiation of product. Conformity with the standard does not necessarily bring about identity of product. There may be competition through provision of more than the minimum qualities stated. There may be competition in features, such as appearance or accessories, which are not standardized because they are not essential to performance. Competitive design may provide equivalent performance in lighter weight or smaller bulk.

The last consideration suggests that to preserve the maximum benefits of competition, standards of quality should preferably be defined in terms of performance rather than in terms of details of construction and materials which may tend to retard technology by restricting freedom of design.

Safety Standards:

Safety standards are a special kind of quality standards. Governmental units, states, and municipalities generally have their own safety standards in the shape of laws or regulations. These are sometimes the result of inadequate knowledge and thus fail to promote real safety. They often hinder competition and increase the cost to the consumer because they are unduly restrictive or burdensome and exclude materials or methods which are, in fact, safe. Worst of all, the variety of regulation may throw up a trade barrier more formidable than tariffs or quotas and fragment the market.

The influence of safety standards promulgated by competent organizations tends to remedy these defects. To the extent that national and international standards become law, they expand the market by removing trade barriers. By promoting true knowledge of what is required for safety, they eliminate useless and preferential restrictions. Like other standards of quality, safety standards define a

minimum—in this case, the minimum necessary to secure reasonable safety. There may be some room for debate as to how much safety this is, but, in practice, judgment on this score will usually be confined within narrow limits.

It is extremely important that safety standards, since they may be enacted into law or used by inspection authorities, avoid any discrimination between competing materials or methods. They must expressly provide for the use of any material or method believed to be reasonably safe.

Standardization Involving Patents:

The adoption by all competitors of a standard dependent upon a patented article or process, or incorporating a patented feature, may discriminate against producers without access to the patent and add to the lawful patent monopoly the combined economic strength of those developing the standard. Such a standard is to be avoided unless the patent can be made available to all comers on reasonable and equal terms or unless the standard may be satisfied by employing products and processes which are not covered by the patent and which are available at competitive prices. Similar considerations apply in the case of trade secrets and trade names.

Standards of Interchangeability:

Standards of interchangeability enable the production of complementary goods to be coordinated in systems that will fit together and work together regardless of the producer. The standard tire is sure to fit the standard rim, the standard appliance to operate on the standard circuit.

The inconvenience, even the chaos, which would prevail in a modern economy without standards of interchangeability is almost inconceivable.

No more dramatic example of the need for interchangeability and the need for coordination of standards can be found than that of the great fire in Baltimore in 1904. Fire-fighting equipment was sent from Philadelphia and New York to aid the burning city but this apparatus stood by idly while flames consumed 80 city blocks in the business district. *The fire hose couplings from the out-of-town equipment did not fit.* There was no recognized standard for fire-hose couplings. This will not occur again in those cities which are among the more than 6000 municipalities which have adopted the American Standard for fire-hose couplings.

Lack of interchangeability has the effect of an allocation of markets. Through unnecessary differentiation of product, it limits the sources of supply available to the consumer and the markets available to the producer. Every extension of interchangeability is, therefore, a force promoting competition. But even here a word of caution seems appropriate. In many cases adaptation to a standard of interchangeability may prove costly to producers and consumers alike. Because of this fact, it is important that each person affected have an opportunity to participate in such standardization on a fair and nondiscriminatory basis.

Standards to Reduce Variety:

Standards with the functions so far considered have the incidental effect of channelling supply and demand in particular types of products and of reducing the market significance of other types. Standardization for the express purpose of reducing variety is usually referred to as simplification.

Is reduction in variety by itself a legitimate object of standardization, assuming no agreement to produce or sell only standard varieties? It would seem to be unobjectionable when the variations have no relevance to consumer choice. For instance, containers to hold a certain weight of a product may, through custom, be ordered and made in dozens of slightly varying sizes. The selection of a single size or series of sizes as standard might serve all needs equally well and tend to prevent deception or confusion of the consumer. Again, if it is possible to show that lesser number of grades or sizes of a product fulfills every function served by a greater number, the standardization of the lesser number would not hurt competition.

But this condition is not easily met where variations have an appeal to consumer taste. To standardize certain colors, for example, in a product where color is or may be an aesthetic consideration or have sales value would tend to restrict competition in a feature of importance to the consumer. It might be arguable that the inclusion of other shades would be a wasteful practice to be deplored, but it is not the province of standardization to legislate consumer wants. Where the varieties eliminated from the standards have competitive significance and no other purpose for standardization is shown, an inference of agreement to eliminate nonstandard items might be inferred. Such an agreement would under most circumstances be illegal.

Revision of Standards:

Standards are not timeless. Use may reveal defects. Advances in the art may render obsolete their technical basis. Consumer wants may change. Without provision for continuous or periodic revision, standards may tend to choke progress.

Fundamental revisions of standards may present special problems. Because of difficulties of redesign and the expense of retooling, larger companies may be in a better position than smaller companies to change to a new standard. A large company, able to produce an improved product but reluctant to market it without a standard, may be eager for revision; a small company, fearful of cost or of otherwise being put at a competitive disadvantage, may resist it.

In this situation revision should not be forced on those smaller companies unable to make the required changes in design. The commercal advantages of standardization flow from cooperative action and such advantages should only be employed when the standard product may be produced by all competitors without undue hardship or discrimination. This is recognized by most standardization bodies. Their rules usually provide that adoption or revision of standards must be with the concurrence of the great majority of all participating manufacturers with provision for appeal by any manufacturer who believes that the proposed adoption or revision will place him at competitive disadvantage.

Procedures for Standardization:

In my opinion standardization, properly pursued, promotes competition. The possibilities of injury which exist are twofold: injury to a competitor in the same economic group and injury to members of other groups. It is plain that these possibilities are minimized in proportion as all interested groups and all members of each group receive a voice in the process. The greatest safeguards are obtained where the adoption of a standard requires the consensus of all interested groups.

When standardization is carried on by a single economic group, such as a trade association, participation should be open on an equal basis to all members of the group. All participants should have an equal voice in the adoption of the standards. This means that the smallest member has the same voting strength as its largest competitor. Approval of a standard should require a large majority vote. Where reasons are given for a negative vote, opportunity should be afforded for reconsideration of the standard in the light of such comment.

These principles diminish the possibility of injury to a competitor. The possibility of injury to other groups must be guarded against by the establishment of and adherence to policies of the nature I have just described. It is always wise to have adherence checked by legal counsel.

This very brief summary of some of the controlling characteristics of the process of standardization should demonstrate the fact that standardization as such is a lawful cooperative activity. It involves merely the process of reaching agreement on the form and content of a definition of a product or procedure. It is not an agreement to do anything. Legal implications which have arisen in connection with standardization stem not from that process but from combinations or conspiracies intended to employ a lawful means to bring about a restraint or to promote a monopoly.

Pittsburgh Nuclear Activities Council Organized

THE PITTSBURGH Nuclear Activities Council, made up of representatives of 16 technical societies active in the area, has been organized to coordinate the activities of the member societies in the field of nuclear science and technology. At the organizational meeting in Pittsburgh, the Council elected E. B. Gunyou, representing the American Inst. of Chemical Engineers, president; and S. B. Gunst, of the Physical Society of Pittsburgh, secretary-treasurer.

Purpose of the Nuclear Activities Council is to act as a central agency to keep abreast of developments in nuclear science and technology and to assist in the development of this field in the Pittsburgh area. To accomplish this, the Council will coordinate the activities of member societies, investigate the needs for industrial training courses, inventory the area's industrial and institutional facilities for nuclear research, and provide a central nuclear information service agency. In addition, the Council plans to sponsor a series of inter-society lecture courses on nuclear science and act to assist member societies in obtaining qualified speakers in the field.

Societies not yet officially represented in the Pittsburgh Nuclear Activities Council are invited to contact Thomas E. Stelson, Civil Engineering Department, Carnegie Institute of Technology, to arrange for participation in the Council's activities.

Representing ASTM is H. F. Beeghly, head, Applied Science Section, Research Lab., Jones & Laughlin Steel Corp., who serves on the Pittsburgh District Council, and is devoting part of his time to nuclear work. He is also active in ASTM Committee E-3 on Chemical Analysis of Metals.

The Bookshelf

Problems and Control of Air Pollution

F. S. Mallette, Ed., Reinhold Publishing Corp., New York, N. Y., 270 pp., $7.50.

THIS book assembles under one cover, the twenty-five papers presented at the First International Congress on Air Pollution held in New York City in March, 1955, under the sponsorship of the Committee on Air Pollution Control of The American Society of Mechanical Engineers. In this volume are presented authors on various air pollution subjects from the world over—from U. S., Canada, England, France, Italy, Holland, and Portugal. Thus, the international interest in this subject of air pollution control is demonstrated.

In the opening chapter, Sir Hugh Beaver, chairman of the Government (British) Committee on Enquiry into the Nature, Causes, and Effects of Air Pollution, gives a very good historical sketch of the efforts to control air pollution in England spurred on by the London smog disaster of 1952. This is followed by a fine discussion of the public relations aspect of air poliution in the United States by G. Edward Pendray, a management consultant.

Following these presentations are papers by U. S. and Canadian authors pointing to gaps in the available knowledge on air pollution and some current developments in research into several specialized phases of the problem. The current developments touch on such items as diesel engine exhausts, incinerator design, measuring the particle size by light scattering and the Sarnia Survey, Action Without Compulsion.

Perhaps the greatest value of this publication is its complete coverage of the sulfur dioxide problems in air pollution control. Beginning with a dissertation on the world supply of sulfur, there follow various papers on the removal and recovery of sulfur dioxide from various industries, namely, power generation (from the combustion gases), refining, iron and steel making, including coke making and sulfuric acid manufacturing.

The final chapter dealing with experiences in air pollution abroad gives an interesting insight into the practices and approaches to dealing with this subject in Holland, Italy, Portugal, and France.

The conference from which the papers were derived set out to focus attention on the international aspect of air pollution. The conference accomplished this purpose, and, therefore, this publication reporting the conference also meets this goal. This book then becomes a valuable addition to the air pollution library, particularly for reference by the professional air pollution engineer.

C. W. GRUBER

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Handbook of Engineering Materials

1st Ed., Douglas F. Miner, John B. Seastone, Editors, John Wiley & Sons, Inc., New York, N. Y., 1380 pp., $17.50.

THIS is a monumental work. It represents the combined efforts of fifty-one individual contributors whose work has been capably compiled and edited. In the Foreword, the editors point out a number of factors effecting selections of material; various materials compete in properties, combination of properties, cost, ease of fabrication and availability. These factors are usually interrelated and should be considered together in the selection of materials for particular applications.

The editors point out that, "In using physical data presented in this Handbook, it should be observed that much of the information was obtained at room temperature and at conventional loading rates. Other temperatures, either higher or lower, and other rates of load application may have very marked effects on properties." A further word of caution is concerned with the variability of materials and the importance of verification of material choice by actual production and field test on a substantial number of samples of the production in question. Properties of materials do not possess the unchangeable reliability of tables of logarithms, and the information in this handbook, in the words of the editors, "does not obviate the need for engineering judgment based on a thorough study of the materials problems being considered."

ASTM members and committee members are well represented among the contributors, there being fourteen of the total who are closely associated with the Society. Most of the others come from organizations that are well represented on technical committees of ASTM.

The book includes four major sections entitled, General Information on Materials, Metals, Non-metals, and Construction Materials.

Section I includes some worthwhile information on standardizing agencies. The reference to ASTM acknowledges the fact that most purchasers of raw materials refer to ASTM Standards. While there is good coverage of Statistics in the Application of Materials in the first section and references are included at the end, there is no mention of the important ASTM publications in this field. There is a very clear presentation of conversion tables—a very important part of any engineering handbook owing to the multiplicity of units used for various physical quantities.

Also included in the first section are tables giving physical properties of a large number of liquids and solids. Use of these tables can provide initial general selection of materials and classes of materials.

The section on Metals devotes individual chapters to ferrous metals, aluminum, magnesium, copper and its alloys, zinc, nickel and its alloys, other pure metals, and special-purpose metals and alloys. A great many properties are covered, and there is special reference to certain applications for which indicated properties are particularly suitable. The importance of temperature in the application of various metals is emphasized by the inclusion of strength data over a range of temperature. The final chapter of this section treats corrosion. The emphasis of this chapter is on the effects of various reagents on metals, and there is almost no mention of the many methods by which coatings both of the ceramic and organic variety are used under corrosive conditions. Plastics now widely used for piping, duct work, etc., under corrosive conditions are not mentioned in this chapter, though later in the book, chemical resistance tables for plastics are included.

Non-metals included in the third section include wood, paper, fibers, plastics and rubber, finishes, fuels, carbon products, ceramics, industrial chemicals, and lubricants. Properties given are related to common uses as is the case throughout the book. Comparative data on large numbers of similar materials are given in the same tables or charts, thus rendering it relatively easy for the engineer to narrow down the number of possible materials for a particular application without consulting a large number of reference books.

The final section on construction materials covers both metals and nonmetals which fit into this category, thus facilitating the selection of a material for an application without bias for one type of material over another. For example, materials for drainage include concrete for box conduits and concrete pipe, vitrified clay pipe, cast iron pipe, cement-asbestos pipe, and corrugated metal pipe. Also fiber rope and wire rope are considered in the same chapter.

Some general observations are that there are liberal references to ASTM Standards, the book is well balanced with respect to treatment of one material as compared to that of another, and this reviewer has found no important omissions considering the large scope covered. However, in a work of this kind it is inevitable that some of the material included may be out of date and evidence of this is the reference to many ASTM standards of old designations which have since been revised. Another example is the inclusion of a table of data from the 1949 edition of the ASHVE[1] Guide which is issued in a new edition anually. The corresponding table in the 1955 edition contained a number of revisions. Engineers who desire the latest up-to-date information on materials would do well to refer to the latest editions of other handbooks and publications in that particular field.

Despite the few shortcomings mentioned above, the *Handbook of Engineering Materials* represents a very worthwhile addition to any engineer's bookshelf especially if he has anything to do with the selection and application of engineering materials. F. Y. S.

[1] American Society of Heating and Ventilating Engineers, now ASHAE: American Society of Heating and Air-Conditioning Engineers.

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Nuclear Reactors for Industry and Universities

Instruments Publishing Co., Pittsburgh 12, Pa., $2

THIS book should prove an invaluable reference for any university or laboratory contemplating a research reactor of its own. Nationally known authorities have been drawn together to write chapters on specific aspects of such a problem. The chapters cover the nature of nuclear energy, the benefits that research reactors can confer, the types of radiation emitted, the means of controlling reactors, health measures requisite for guarding against injury, cost studies, and legal aspects of reactor installation and operation.

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Atomic Energy Publications

THE VOLUMES described briefly below are designed to furnish a practical basic source of information on nuclear energy and its many applications. These publications were assembled by the United States Atomic Energy Commission for presentation to the delegates of each nation attending the International Conference on the Peaceful Uses of Atomic Energy in Geneva. They are currently available in paper covers from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Isotopes—an 8-Year Summary of Distribution.—A detailed account of isotope utilization during the first eight years of the Commission's distribution program. It is also a supplement to the three-year and six-year reports of similar title issued by the Commission in 1949 and 1951. This report is a useful reference to the uses of isotopes and a bibliography of published articles on isotope work. $2.

Chemical Processing and Equipment.—This publication describes the chemical and engineering aspects of processing materials associated with nuclear reactors. It includes descriptions of radiochemical laboratories, remote control handling equipment and the like. $2.

Neutron Cross Sections.—A compilation of data in tabular and graphic form prepared by the AEC Neutron Cross Section Advisory group. Cross-section values for nuclides, elements, and compounds are given for neutrons ranging in energy from 0.0001 electron volts to 100 Mev. $3.50.

Reactor Handbook.—A condensed and reliable source of nuclear reactor data. Volume I—Physics, two sections, Reactor Physics and Radiation Shielding. $4.25; Volume II—Engineering, eight sections. Light- and Heavy-water-cooled Systems, Liquid-metal-cooled Systems, Gas-Cooled Systems, Aqueous Fuel Systems, Liquid-Metal Fuel Systems, Fused Salt Systems, Handling and Control, and Reactor Designs. $5.50; Volume III—Materials, Section I, General Properties. $3.50.

Research Reactors.—A volume describing the nuclear research reactors developed in the national atomic energy program. $2.

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OTS Research Reports

U. S. Department of Commerce, Washington 25, D. C.

Characterization of C_{21}–C_{30} Hydrocarbons and Their Mixtures

IN THIS study, the morphological, X-ray and optical properties of the ten straight chain hydrocarbons from $C_{21}H_{44}$ to $C_{30}H_{62}$ are presented with as much information as possible on the polymorphic forms of each member of the series. The relationship between the crystallographic properties of these waxes and their behavior in lubricating oils is discussed. Representative binary composition diagrams were determined by a coordinated microscopical and X-ray diffraction approach. 104 pp.; price, $2.75.

Sorption of Water Vapor by Cellulosic Cushioning Materials

SEVEN cellulosic materials frequently used to cushion sharp-

cornered items packed in desiccated packages were tested at 100 F and 95 per cent relative humidity to determine how much water vapor would be sorbed, both in the presence of silica gel desiccant and when a desiccant was not used.

The tests indicated that 20 per cent of the total water vapor pick-up of cushioning material-desiccant combinations is attributable to the cushioning material, and that 11 times more water vapor is sorbed by the cushioning materials when exposed in desiccant combinations than when the same cushioning materials are exposed without a desiccant.

The report details experimental procedure and lists trade names and manufacturers of the materials tested. 11 pp.; 50 cents.

Evaluation of Experimental Wool Synthetic Blends in Air Force 18-oz Blue Serge

TWENTY-ONE wool serge fabrics were tested at Wright Air Development Center laboratories to determine the comparative qualities of 100 per cent wool standard serge and the same fabric with varying percentages of the "miracle" fibers and viscose rayon. Tests were made of breaking strength, shrinkage, abrasion, wrinkle recovery, flame and wicking time, and char rate.

The report shows that certain synthetic blends increased breaking strength and abrasion resistance, with marked improvement as the per cent of synthetic fiber was increased. However, the addition of all synthetic fibers increased the rate of burning and wicking and decreased wrinkle recovery. These tests apply only to 18-oz standard blue serge, and further service tests are recommended in the report. 26 pp.; price, 75 cents.

Crack Arresting by Overlays of Notch-Tough Weld Metal

Crack-starter explosion tests were made to demonstrate the feasibility of using overlays of notch-tough welds to prevent brittle fracture in structural mild steels. Investigation leads to the recommendation that notch-tough weld deposits be considered for the protection of welded structure by application at points where brittle fractures are known to initiate. This method is considered practical for application to existing or new structures, according to Naval Research Laboratory, which made the investigations. PB 111781, 9 pp., 50 cents.

Control Method of Chemical Analysis of Barium Titanate

As a part of an effort to improve the quality and reproducibility of $BaTiO_3$ ceramics, a procedure for analysis of $BaTiO_3$ for both major and minor constituents is presented. Two companies participated in this research—the Brush Laboratories Co. and the Titanium Alloy Manufacturing Division of the National Lead Co. The contributors to this report conclude that the procedures developed in this study are dependable and accurate. Gravimetric and volumetric analysis is used for the major constituents and the principal minor constituents. Flame photometry is used for minor constituents which are particularly difficult to analyze by more normal procedures. PB 111780, 25 pp., 75 cents.

A Field Evaluation of Termite Repellents

Field investigations were carried out in the jungles of Panama by the Naval Research Laboratory. Wood panels were impregnated with compounds of both known and unknown toxic qualities and exposed to attack by termites. Of the compounds tested, pentachlorophenol, copper and zinc pentachlorophenate, napthenate, hexachlorophenol zinc dithiocarbamate, creosote fortified with intermediate boiling fractions, creosote residue, creosote minus tar acids and tar bases, and creosote minus the tar bases were most effective in repelling termite attack.

Impregnation was carried out by a high-pressure technique or an immersion technique, with the level of impregnation varying from 0.8 to 5.0 per cent and periods of exposure from 22 to 30 months. The report details methods of impregnating and testing, and tables show ratings of the 37 compounds. PB 111737, 10 pp., 50 cents.

An Investigation of the Dynamic Mechanical Properties of Polymethyl Methacrylate

Dynamic mechanical properties of polymethyl methacrylate are studied over a frequency range of 6×10^4 to 1.6×10^2 cps and a temperature range of -20 to 80 C. A modified Kimball type testing machine was developed for this research. The results on polymethyl methacrylate indicate that three mechanisms of relaxation are involved in the response of the material in this frequency and temperature range. The importance of dynamic mechanical properties to the practical engineering design of plastic components is discussed. It is suggested that three-dimensional plots of modulus or loss factor *versus* frequency and temperature is the best method of describing the mechanical behavior of plastics at their use conditions. PB 111642, 35 pp., price $7.

Adsorption Studies on Polyvinyl Acetate and Polyvinyl Butyral Wash Primers

Contained in this progress report (February 1–July 31, 1954) are experimental results indicating that the amounts adsorbed are functions of molecular weight, but these functions vary greatly with the solvent, running inversely with solvent power. Also discussed tentatively on the basis of available information in this report is the general function of the resin in the wash primer, and as an assistant for corrosion protection. 48 pp.; price, $1.25.

Research and Development of High-Strength Reinforced Plastics for Ordnance Use

Parallel glass fiber structures have been developed for the reinforcement of plastics with good handling characteristics through the use of cured thermosetting resin binder systems. When the binder is applied to the fibers as they are newly formed, a degree of adhesion is established which raises flexural strength values of polyester laminates made from them from 65,000 psi to 120,000 psi and also increases modulus values. The physical-chemical properties of the fibers and their relation with plastics have been studied. The study attempts to establish facts which will permit the production of more useful products and explain the failure of structures in the past when subjected to only moderate loadings. 54 pp.; price $1.50.

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Materials of Construction

A. P. Mills, H. W. Hayward, and L. F. Rader, John Wiley & Sons, Inc., New York, N. Y., 650 pp., $7.50.

THIS excellently prepared sixth edition, by Prof. Lloyd F. Rader, University of Wisconsin, has been revised and expanded to include the latest available data. The original purpose of the late Professor Mills was to provide a textbook covering the manufacture, properties, and uses of materials of engineering construction.

A new chapter has been written on Mineral Aggregates which discusses by-product and processed aggregates as well as natural aggregates. One other new chapter describes laminates and adhesives and their use in laminated structures.

Many of the chapters have been revised to include the most recent advances in these fields. In the section on Metals, service requirements have been revised to cover recent developments in progressive fracture under repeated stresses, creep, behavior of metal under high and low temperatures, impact testing, wear, and corrosion. The classification of structural clay products has been revised to conform with the present practice; the subject of concrete now includes air-entrained concrete and modern methods of proportioning; tim-

ber connectors are described, and a new section on Acoustical Materials includes classifications of the various types.

The general subject of the book has been retained, with fundamentals being reviewed in the early part of the book, followed by separate chapters on individual materials of construction which give useful information on the manufacture, properties, methods of testing, and applications of these materials. Many references to ASTM standards are found throughout these chapters.

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Proceedings, American Railway Engineering Assn.

Vol. 56, 1227 pp. (1955)

THIS issue includes special reports on: Static and Dynamic Effects of a Bridge Supported on Concrete-Filled Pipe Piling, Passenger Ride Comfort on Curved Track, Comparison of Structural Joints Connected by High-Strength Bolts and Structural Joints Connected by Rivets and High-Strength Bolts, Curve Wear by Diesel Locomotives, Dynamic Rail Creepage Forces Exerted on Ties by Rail Anchors and the Static Load Required to Move Ties in Ballast.

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The Welding of Austenitic Chromium Nickel Steel Piping and Tubing

American Welding Society, 33 W. 39th St., New York, N. Y.; $1

THIS committee report is intended to serve as a guide so that difficulties in the welding of austenitic stainless steel may be avoided. Although these steels have been satisfactorily welded for many years, certain welding problems have been reported by industry.

The report is divided into seven sections wherein the major welding considerations are presented, followed by a discussion of the suitability of various stainless steel grades for welding pipe, suitable welding processes, the proper selection of filler metal, the role of the welded joint, proper pipe welding techniques, and inspection methods.

An invaluable aid is a group of tables which list the standard AISI, ACI, and ASTM types of austenitic stainless steels and the correlation between these types. Of particular value is a table giving the specific welding rod or electrode to be used for welding each type of stainless steel.

Although this report was written specifically for piping and tubing, it is equally applicable to all forms of austenitic stainless steels.

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Principles of Emulsion Technology

1st Ed., Paul Becher, Pilot Book No. 5, Reinhold Publishing Corp., New York, N. Y., 149 pp., $2.95.

THIS book is written for those who have studied chemistry and are now desirous of learning more about both theoretical and applied emulsions than the passing mention given the topic in physical chemistry courses. Although the theoretical discussion is largely physico-chemical, those without formal training in the subject should be able to follow the presentation with minimum difficulty.

The worker in the field will, perhaps, find little new in the portions of this volume dealing with applied problems; what has been attempted here is the presentation of general principles in terms of practical examples. As is well known, the actual formulation of emulsions is still largely an art; thus the principles indicated in this book are intended primarily to serve as a guide to emulsion technology.

Chapter headings are: Dispersions and Emulsions, Surface Activity, Theory of Emulsions, The Chemistry of Emulsifying Agents, Emulsification Equipment, The Testing of Emulsion Properties, Emulsion Formulation, and Demulsification. Also included are General References, and Index.

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Electro-Technology

1st Ed., M. G. Say, Philosophical Library, Inc., New York, N. Y., 167 pp., $6.

THIS book presents in concentrated form the electro-technical basis of the phenomena which are important in light and heavy electrical engineering. An introductory section with conduction and magnetic and electric field effects, and a comprehensive list of definitions is given. The rationalized m.k.s. system of units is used throughout.

The second part of the book gives a complete guide to the handling of circuit problems. Two-terminal and four-terminal cases are dealt with, and balanced and unbalanced three-phase circuits. A feature is the collection of network theorems, which should be of great help to those who have to work out electrical quantities in all types of circuits and networks.

The book is comprehensive and clearly written, and will be found useful as a textbook for students and a book of reference for practicing engineers in all branches of the electrical industry.

To ASTM Nonmembers: The Society welcomes inquiries on the "Advantages of Membership"

To the ASTM Committee on Membership
1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send me information on Membership in ASTM and include a membership application blank.

Signed _____

Address _____

Date _____

Proceedings, Third International Symposium on the Chemistry of Concrete, 1952

Cement and Concrete Assn., London, 870 pp. (1954); $9

THE FIRST international congress in which the chemistry of cement was discussed was organized by the International Association for Testing Materials (the American branch of which became ASTM) and was held in Stockholm in 1897.

The first symposium devoted to the chemistry of cement was held in 1918 in London and the second in 1938 in Stockholm. The third and present symposium was divided into four technical sessions presented on successive days. The sessions and their contributors were:

The Constitution of Portland Cement—The Tricalcium Silicate Phase—J. W. Jeffery (U.K.), The Dicalcium Silicate Phase—R. W. Nurse (U.K.), Interstitial Phases in Portland Cement Clinker—Herbert Insley (U.S.A.), The Ferrite Phase—G. Malquori (Italy) and V. Cirilli (Italy)—The Alkali Phases in Portland Cement Clinker—Terry F. Newkirk (U. S.A.), Tricalcium Aluminate—Fred Ordway (U.S.A.), Studies on the Constitution of Portland Cement Clinker—R. H. Bogue (U.S.A.).

The Setting and Hardening of Portland Cement—The Structures of Cement Hydration Compounds—J. D. Bernal (U.K.), The Reactions and Thermochemistry of Cement Hydration at Ordinary Temperature—Harold H. Steinour (U.S.A.), The Reactions of Cement Hydration at Elevated Temperatures—George L. Kalousek (U.S.A.), The Physical Structure of Cement Products and Its Effect on Durability—F. E. Jones (U.K.), Chemical Aspects of the Durability of Cement Products—T. Thorvaldson (Canada).

Special Cements—The Constitution of Aluminous Cement—T. W. Parker (U.K.), Slag Cements—F. Keil (Germany), Expensive Cements—H. Lafuma (France), Oil Well Cements—W. C. Hansen (U.S.A.) Masonry Cement—Charles E. Wuerpel (U.S.A.).

Applications of Research—Thermodynamics of the Cement Kiln—H. Gygi in collaboration with F. Guye (Switzerland), The Influence of the Fineness of Cement Raw Mixes on Their Burnability—T. Heilmann (Denmark), Some Recent Developments in the Design and Construction of Concrete Structures—A. R. Collins (U.K.), Development of Cements for Special Uses in the United States—Myron A. Swayze (U.S.A.), Cement Research and the Future—P. M. Lea (U.K.).

It is not feasible to give an analysis of these papers in this review as each paper represents definitive research, careful consideration of current theories, and a lifetime of experience by each author. It should suffice to say that this most significant symposium covers all phases of cement chemistry, from the initial chemical activity of the first mixture to the continuing growth and degradation of the compounds and crystal structures of hardened cement.

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More AIC Reports Released

ONE HUNDRED and thirty Atomic Energy Commission technical reports have been made available to industry through the office of Technical Services. Release of these reports was made in accordance with a continuing arrangement between AEC and OTS, begun in August with the release of 961 research reports whereby about 100 new reports were made available in the interest of industry each month. The 130 reports were listed in the November issue of *U. S. Government Research Reports.* A reprint of the AEC section of this publication is available from OTS, U. S. Department of Commerce, Washington 25, D. C., price 10 cents. A free list of the 961 reports released in August may also be obtained from OTS.

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Reports on Reinforced Concrete

Reinforced Concrete Research Council 510 Denver National Bank Bldg., Denver, Colo., 50 cents each.

VARIOUS organizations in this country have sponsored, since 1948, joint research on reinforced concrete, this work being carried out under the guidance of the Reinforced Concrete Research Council. The Council has various projects under way to obtain test data which will be useful in the development of a more scientific procedure for the design of reinforced concrete. Reports covering the various investigations are usually published in the *Journal* of the American Concrete Inst., the *Proceedings* of the American Society of Civil Engineers, or by the university conducting the investigations.

In order for the members of the spon-

To ASTM Members: Your help is needed in maintaining that constant increase in ASTM Membership

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To the ASTM Committee on Membership
1916 Race St., Philadelphia, 3, Pa.

Gentlemen:

Please send information on membership to the company or individual indicated below:

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This company or individual is interested in the following subjects: indicate field of activity, that is, petroleum, steels, non-ferrous, etc.

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Signed _____

Date _____ Address _____

soring organizations to be kept informed of the progress of the various investigations, the Council has adopted a policy of securing reports of the various reports and under its own cover distributing them to the sponsoring members.

Extra copies of the following are available:

Bulletin No. 1—A Study of Combined Bending and Axial Load in Reinforced Concrete Members by Eivind Hognestad

Bulletin No. 2—Inelastic Behavior in Tests of Eccentrically Loaded Short Reinforced Concrete Columns by Eivind Hognestad

Bulletin No. 3—What Do We Know About Diagonal Tension and Web Reinforcement in Concrete by Eivind Hognestad

Bulletin No. 4—Yield-Line Theory for the Ultimate Flexural Strength of Reinforced Concrete Slabs by Eivind Hognestad

Bulletin No. 5—Shearing Strength of Reinforced-Concrete Column Footings by Eivind Hognestad

Efficiency and Economy in Government

As ALL know who have some knowledge of the Hoover Commission, efficiency and economy in Government underlie its extensive studies and recommendations. In the recent *Taxpayer's Dollar* issued by the Finance Department of the Chamber of Commerce, there is discussion of interest to all engineers and scientists, entitled "Research and Development."

Preceding this discussion is a series of case histories of the Government in business—steamship lines, scrap preparation, bakeries, clothing manufacture—and in general the Commission recommends that private industry should be called upon to undertake these activities with resultant large savings to the Government. However, in discussing research and development the reverse is true, and here the Commission recommends expenditure increases. The Commission is calling for an expanded and boldly imaginative research program for the Government, particularly in scientific fields.

A total of 229 individual agencies of the Federal Government with budget appropriations for 1956 amounting to $2.4 billion conduct research. The total research and development program extends from abstract science to the practical testing of products developed through research. About 85 per cent of the budgeted expenditure will be spent through the Defense Department, largely in connection with national defense. The remaining 15 per cent is spent by civilian agencies.

The Defense Department

In its study of the Defense Department, the Task Force made the following recommendations:

1. That the military's policy of rotating officers after relatively short assignments should not be applied to personnel in the research and development programs. Professional development of these men suffers from a policy that does not permit them to have a career in their technical field. Such officers should serve for longer periods but receive the same preferment and promotion as if rotated.

2. That a Senior Civil Service is necessary to retain professionally trained civilian personnel. Existing pay scales and number of high-level positions are not adequate to maintain the high degree of technical competence required in these programs.

3. That a committee reporting to the Assistant Secretary for Research and Development and composed of outstanding scientists in the basic and applied sciences be established to keep the Department posted on radically new scientific developments with emphasis on new weapons.

4. That basic research be raised substantially over its $20,000,000 expenditure level and that research and development design operations could be advantageously shifted to the civilian economy.

Civilian Agencies

In civilian agencies of the Government, research activities are centered largely in the Departments of Agriculture, Interior, Commerce, and Health, Education and Welfare where they cover a wide range such as farm and land management, livestock and wildlife, nutrition, mining, meteorology, engineering, and medicine. Here the Commission recommends an increase in basic research in the laws of nature and the nature of materials, and greater support to basic medical and research projects.

Spectrographic Standard Samples of Stainless Steel

THE National Bureau of Standards has announced the availability of six new standard samples of stainless steel. The samples, carefully analyzed and certified for composition, are designed for calibrating and checking spectrochemical methods of analysis.

The new stainless steel standards are certified for concentrations of six major and minor elements: manganese, silicon, copper, nickel, chromium, and molybdenum. Samples are available in two forms: rods $\frac{7}{32}$ in. in diameter and 4 in. long, and rods $\frac{1}{2}$ in. in diameter and 2 in. long. Both forms serve as electrodes for spark excitation in spectrochemical analysis.

Since spectrochemical methods of analysis are both fast and accurate, such methods have been increasingly applied to the analysis of complex steel alloys. Anticipating the growing need of industry for suitable standards, the Bureau began preparing the stainless steel samples several years ago. Six heats of metal were contributed by the Uddeholm Co. of Sweden, which prepared the steels to desired composition and fabricated the metal into rods. A grant from the American Iron and Steel Inst. assisted the Bureau in homogeneity testing and analysis. Chemical analyses were made by four cooperating laboratories: Allegheny-Ludlum Steel Corp., Armco Steel Corp., Wilbur B. Driver Co., and NBS.

The rods have a uniform grain structure resulting from hot-rolling and annealing the cast metal. The surfaces of the rods were finished by centerless grinding. The homogeneity of the rods, both in cross and longitudinal sections, was studied by spectrochemical analysis at the Bureau and was found satisfactory with respect to the concentrations of the certified elements.

The standards can be applied directly to the analysis of stainless steel rods prepared in a similar manner and with similar dimensions. However, when the standards are applied to the analysis of steel samples prepared by other procedures, adjustments may be required to correct for variations introduced by physical differences.

The stainless steel standards may be obtained from the National Bureau of Standards for a fee of $8 each.

COMPOSITION OF NBS SPECTROGRAPHIC STANDARD SAMPLES OF STAINLESS STEEL.

Samples[1]		Manganese, per cent	Silicon, per cent	Copper, per cent	Nickel, per cent	Chromium, per cent	Molybdenum, per cent
No. 445	No. 845	0.77	0.53	0.065	0.28	13.30	0.92
No. 446	No. 846	0.53	1.20	0.19	9.10	18.37	0.43
No. 447	No. 847	0.23	0.37	0.19	13.26	23.73	0.059
No. 448	No. 848	2.10	1.25	0.16	0.52	9.10	0.33
No. 449	No. 849	1.62	0.68	0.21	6.62	5.48	0.15
No. 450	No. 850	...	0.12	0.36	24.8	2.99	...

[1] Sizes: 400 Series, rods $\frac{7}{32}$ in. in diameter, 4 in. long. 800 Series, rods $\frac{1}{2}$ in. in diameter, 2 in. long.

A Performance Test for the Potential Sulfate Resistance of Portland Cement

Reported by the Working Committee on Sulfate Resistance of ASTM Committee C-1 on Cement[1]

This report gives the results of a cooperative series of tests designed to develop a performance test for the potential sulfate resistance of portland cements. The method of test consists of measuring the expansion of mortar prisms containing excess calcium sulfate, equivalent to a total SO_3 content of 7.0 per cent by weight of the cement. The expansion of the mortar prisms is an index of the potential sulfate resistance of the cement. The results presented in this report indicate that: (1) significant expansion occurs within 28 days, (2) reproducible results can be obtained in different laboratories, (3) the expansions discriminate between different cements, (4) there is a general relationship between the 28-day expansion of the mortar prisms and the $3CaO \cdot Al_2O_3 (C_3A)$ content of the cement, and (5) there is a relatively good relationship between the 28-day expansion of the mortar prisms and the performance of concretes exposed to sulfate soils.

THE DISINTEGRATION of portland-cement concrete as a result of contact with alkaline sulfates is a problem of long standing in many localities. The areas of so-called "alkali-soils" are sufficiently widespread to justify consideration of sulfate resistance in the specifications for portland cement. The problem has been studied by many investigators during the past 60 yr (**1**).[2] The chemistry of the reactions is consequently well understood. The Advisory Committee for the Long-Time Study of Cement Performance in Concrete considered the problem of sufficient importance to include, in that study, a project in which concretes made from different cements were exposed to alkaline soil waters under field conditions (**2**).

The problem of sulfate resistance is recognized in the ASTM Standard Specifications for Portland Cement (C 150)[3] and Standard Specifications for Air-Entraining Portland Cement (C 175).[3] In these specifications the sulfate-resistant cements are defined in terms of chemical limitations. Types II and IIA cements are recommended for use in general concrete construction exposed to moderate sulfate action, and type V cement for use when high sulfate resistance is required. The chemical limitations in the current specifications appear to be adequate for the selection of portland cements that will produce concrete having a high resistance to sulfate waters. Good quality concretes made with portland cements of types II, IIA, and V have given excellent performance under adverse conditions of alkaline sulfate exposure. However, such chemical limitations do not make allowance for new or improved cement manufacturing procedures or the use of additions such as air-entraining agents, reactive siliceous admixtures, or other additions that may produce sulfate-resistant cements.

A performance test for sulfate resistance would be desirable. The Working Committee on Sulfate Resistance has pursued the development of a performance test for a number of years. The results of previous studies have been directed to measuring the expansion of lean mortar bars immersed in sulfate solutions and an evaluation of the sulfate susceptibility test. The results of these studies have been published in two reports (**3,4**). Each method of test used in these previous studies did have considerable merit. However, the degree of reproducibility of results obtained by different laboratories was not satisfactory to justify the recommendation that either method would be acceptable as a proposed ASTM Method of Test for Sulfate Resistance.

The Working Committee on Sulfate Resistance initiated a new cooperative series of tests in 1953 using a new procedure for determining the potential sulfate resistance of portland cements. The method of test consists of measuring the expansion of 1:2.75 graded Ottawa sand mortar prisms containing excess calcium sulfate equivalent to a total SO_3 content of 7.0 per cent by weight of the cement. The mortar prisms were cured in the molds one day and then stored in water at 23 ± 1.7 C (73.4 ± 3 F). The percentage expansion of the mortar prisms was calculated and recorded as the per cent change in length calculated on the basis of the length at the age of one day. Thirteen portland cements representing one or more of each of the five ASTM types were used in the test program. Two of the cements were used with an air-entraining agent added at the mixer to provide air-entrained mortars. The 13 laboratories participating in this cooperative series of tests are given in Table I.

The results obtained by the cooperative series of tests were sufficiently encouraging to justify extending these studies. The Research Laboratories of the Portland Cement Assn. then made the mortar bar test using 25 additional cements. All of these 25 cements and 10 of the cements used in the coopera-

TABLE I.—LABORATORIES PARTICIPATING IN SULFATE RESISTANCE TEST PROGRAM.

Participating Laboratory	Representative
California Division of Highways	F. N. Hveem
California Portland Cement Co.	W. C. Hanna
Canada Cement Co. Ltd.	W. S. Weaver and L. J. Shipley
Lone Star Cement Corp.	M. A. Swayze and J. L. Sawyer
Louisville Cement Corp.	E. J. Wechter
National Bureau of Standards	R. L. Blaine
National Research Council of Canada	E. G. Swenson
Pennsylvania-Dixie Cement Corp.	L. C. Hawk and R. F. Houser
Permanente Cement Corp.	O. E. Jack
Portland Cement Assn.	William Lerch
U. S. Bureau of Reclamation	W. H. Price
Universal Atlas Cement Co.	W. C. Hansen
Waterways Experiment Station, Corps of Engrs., U. S. Army	Herbert Cook and Thomas B. Kennedy

NOTE.—The laboratories are not listed in the order in which they appear in the tabulation of test data.

[1] This report presents the results of a cooperative test program, conducted by the Working Committee on Sulfate Resistance of ASTM Committee C-1 on Cement, in which a method of test for determining the potential sulfate resistance of portland cement was studied. The Working Committee on Sulfate Resistance consists of William Lerch, *Chairman*, F. N. Hveem, W. S. Weaver, D. G. Miller, E. J. Wechter, and E. G. Swenson.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

[3] 1955 Book of ASTM Standards, Part 3.

tive tests were used in concretes in the sulfate resistance project of the Long-Time Study of Cement Performance in Concrete (2). Thus there are data available to evaluate the merits of the laboratory test in relation to the field performance of concretes.

Cements

Thirty-eight cements representing the five ASTM types of portland cement were used in the test program. The first digit of the cement number indicates the type. Twenty-two of the cements are among those shown in the previous report by Wolochow (4), and they are identified by the same number as in that report.

Two of the cements were used with an air-entraining agent added at the mixer in the amount required to produce air contents of 10 to 12 per cent and 18 to 20 per cent in the 1:4 standard Ottawa sand mortar, as prescribed in Sections 4 and 5 of the Method of Test for Air Content of Hydraulic Cement Mortar (C 185).[3]

The chemical analyses and calculated compound composition of the cements are shown in Table II. The chemical analyses were made according to the Method of Chemical Analyses for Portland Cement (C 114)[3] and corrections were made for minor oxides as shown in Table II. With these corrections, cement No. 14 meets the requirements of type II cement whereas the first digit of the number classifies it as a type I cement.

Mortar Bar Test

The method of test consists of measuring the expansion of mortar prisms containing excess calcium sulfate, equivalent to a total SO_3 content of 7.0 per cent by weight of the cement. The expansion of the mortar prisms is an index of the potential sulfate resistance of the cement. The method of test is described in detail in Appendix I, a proposed Method of Test for Sulfate Resistance of Portland Cement.

Reproducibility of Results

The results obtained by the 13 participating laboratories are shown in Table III. This table shows the average mortar prism expansion for all laboratories and the maximum and minimum values reported by individual laboratories for ages of 7, 14, 21, and 28 days, 3 months, and 1 yr. Figure 1 shows the expansions reported by the individual laboratories and the average value for all laboratories for the 28-day tests. The variations between results obtained by the different laboratories are of about the same order for all ages of test as those shown in Fig. 1 for the 28-day tests.

Each laboratory fabricated three specimens from each of two batches made on different days. Figure 2 shows the variations in the 28-day expansions of individual specimens within each laboratory for four of the cements. The four cements were selected to cover the range of expansion developed by the 13 cements used in the cooperative tests.

It will be noted from Fig. 1 that the variations in the results obtained by the different laboratories are smaller for cements that show low expansions than for those that show high expansions. Likewise the results shown in Fig. 2 indicate that the variations in the expansions of individual specimens in each laboratory are smaller for cements that show a low average expansion than they are for cement No. 31 that shows a high expansion. This is an encouraging feature of the test. The cements that show low expansions would be sulfate-resistant cements and it is for this type of cement that it is desirable to develop an accurate and reproducible test. The cements that develop high expansion would not be considered as sulfate-resistant, and for these cements all of the laboratories reported large expansions.

An examination of the data shown in Table III indicates that a major part of the variation in results reported by different laboratories was in the expansions reported for the 7-day tests. A similar examination of the data for the expansions of individual specimens within each laboratory (data not included in this report) likewise shows that a major part of the variation appeared in the expansions reported for 7-day tests. These observations suggest the possibility that additional precautions in making the initial one-day reading

TABLE II.—OXIDE AND CALCULATED COMPOUND COMPOSITION OF CEMENTS, CORRECTED FOR MINOR OXIDES.

SiO_2—corrected by subtracting two thirds of the insoluble residue from SiO_2 as determined.
Al_2O_3—corrected by subtracting one third of the insoluble residue, the R_2O_3 and TiO_2 from Al_2O_3 as determined.
CaO—corrected by subtracting free CaO from CaO as determined.

Cement	Major Oxides, per cent									Calculated Potential Compound Composition, per cent			
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Free CaO	C_3S	C_2S	C_3A	C_4AF
Type I Cements													
No. 11	20.74	5.61	2.37	63.32	3.58	1.59	0.22	0.56	0.43	54.5	18.4	10.9	7.2
No. 11T	20.77	5.63	2.33	63.34	3.72	1.53	0.21	0.55	0.47	54.4	18.5	11.0	7.1
No. 12	21.45	5.77	2.41	63.51	3.11	1.55	0.32	0.43	0.11	48.9	24.6	11.2	7.3
No. 12T	21.55	5.67	2.32	63.56	3.07	1.54	0.32	0.41	0.12	49.1	24.8	11.1	7.1
No. 13	22.18	4.70	2.12	64.22	1.07	1.62	0.02	0.20	1.61	53.6	23.2	8.9	6.4
No. 14	22.17	4.62	3.03	62.86	2.37	1.73	0.03	1.40	0.19	47.1	28.1	7.1	9.2
No. 15	20.30	5.30	2.46	66.56	0.71	1.92	0.07	0.25	0.44	72.0	3.9	9.9	7.5
No. 16	21.38	4.66	3.52	63.85	1.92	1.71	0.25	0.46	0.73	56.2	18.9	6.4	10.7
No. 16T	21.36	4.74	3.41	63.55	2.01	1.84	0.25	0.46	0.75	54.4	20.2	6.8	10.4
No. 17	21.46	5.40	3.06	64.77	1.10	1.72	0.07	0.48	0.42	55.0	20.0	9.1	9.3
No. 18	21.35	6.02	2.25	63.71	2.13	1.83	0.15	0.14	0.33	48.2	24.9	12.2	6.8
No. 18T	21.54	6.05	2.18	63.85	2.14	1.68	0.14	0.14	0.38	47.6	25.9	12.4	6.6
Type II Cements													
No. 21	23.71	3.97	3.21	63.98	1.18	1.24	0.23	0.44	0.65	45.4	33.7	5.1	9.8
No. 21T	24.00	4.10	3.22	63.89	1.28	1.27	0.24	0.45	0.60	41.9	37.2	5.4	9.8
No. 22	22.45	4.49	3.85	62.72	3.10	1.41	0.24	0.39	0.05	45.0	30.5	5.4	11.7
No. 23	21.43	4.27	5.44	63.89	0.85	1.50	0.61	0.14	0.43	56.4	18.9	2.1	16.6
No. 24	20.84	4.77	4.85	60.51	3.07	1.75	0.03	1.33	0.88	43.9	26.6	4.4	14.8
No. 25	22.60	4.53	4.86	61.90	2.24	1.86	0.21	0.60	0.21	37.5	36.5	3.8	14.8
No. 2-I	21.70	4.38	4.35	63.70	1.46	1.69	0.11	0.56	0.35	53.9	21.6	4.3	13.2
No. 2-L	23.05	3.75	3.53	62.42	1.70	1.67	0.10	0.48	0.62	43.9	33.0	4.0	10.7
No. 2-M	22.51	4.61	5.49	62.72	0.88	1.48	0.12	0.62	0.56	45.2	30.5	1.3	16.7
No. 2-S	23.93	3.40	3.00	63.24	1.77	1.74	0.16	0.41	0.79	43.4	35.9	3.9	9.1
Type III Cements													
No. 31	20.36	4.96	2.11	63.28	3.20	2.23	0.26	0.26	1.45	60.1	13.0	9.6	6.4
No. 33	20.03	5.08	2.52	63.81	1.38	2.31	0.24	0.46	1.83	63.2	9.8	9.2	7.7
No. 33T	20.46	5.04	2.42	63.81	1.47	2.19	0.23	0.50	1.84	60.6	13.0	9.3	7.4
No. 34	20.40	3.89	3.03	63.32	2.50	1.72	0.29	0.29	2.27	67.3	7.7	5.2	9.2
No. 3-L[a]	21.39	1.88	5.08	65.31	1.76	2.32	0.08	0.14	0.35	73.7	5.7	...	9.0
Type IV Cements													
No. 41	22.95	4.48	4.98	59.16	2.72	1.98	0.03	1.22	0.44	23.5	48.1	3.4	15.2
No. 42	26.25	2.76	2.71	62.85	1.84	1.52	0.14	0.29	0.21	29.5	53.0	2.7	8.2
No. 43	23.55	4.51	4.22	61.54	1.48	1.97	1.06	0.10	0.12	29.5	45.2	4.8	12.8
No. 43A	25.24	3.64	3.06	63.29	0.99	1.87	0.35	0.01	0.35	32.4	48.2	3.9	9.3
Type V Cements													
No. 51	24.43	2.94	3.28	63.76	1.64	1.40	0.07	0.27	0.54	45.4	35.8	2.2	10.0
No. 5-C	22.86	3.31	4.08	62.79	2.39	2.12	0.30	0.34	0.41	47.7	29.6	1.9	12.4
No. 5-I	23.10	3.28	4.71	63.29	1.18	1.68	0.08	0.37	0.38	48.5	29.7	0.7	14.3
No. 5-L	24.10	2.92	3.86	62.84	1.37	1.74	0.05	0.29	1.06	42.5	37.0	1.2	11.8
No. 5-M	25.01	2.98	3.65	61.79	1.13	1.74	0.13	0.43	0.87	31.2	48.2	1.7	11.1
No. 5-P	24.61	2.14	2.54	64.83	0.89	1.78	0.11	0.20	0.69	53.7	30.1	1.4	7.7
No. 5-S	25.27	2.78	3.27	62.72	1.48	1.46	0.14	0.36	0.93	35.7	45.5	1.8	10.0

[a] Cement 3-L contains 3.6 per cent C_2F.

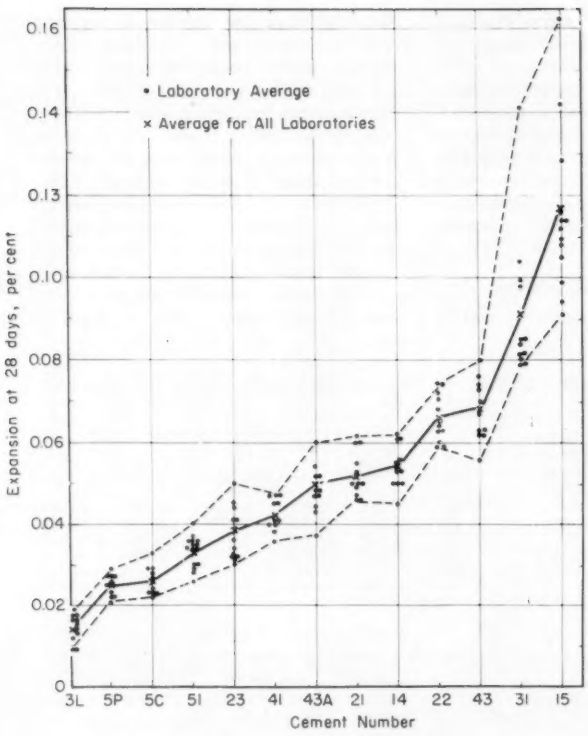

Fig. 1.—Expansion of Mortar Prisms at 28 Days.

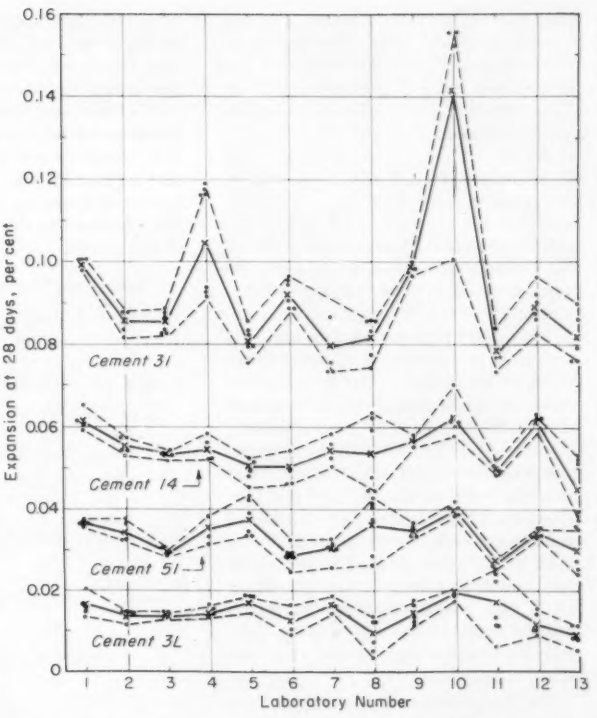

Fig. 2.—Variations Among Individual Specimens in Each Laboratory.

TABLE III.—EXPANSION OF MORTAR PRISMS—AVERAGE FOR 13 LABORATORIES AND MAXIMUM AND MINIMUM VALUES REPORTED BY INDIVIDUAL LABORATORIES.

Cement	No. 15	No. 14	No. 21	No. 21-AE1	No. 21-AE2	No. 22	No. 23	No. 31	No. 3L	No. 41	No. 43	No. 43A	No. 51	No. 5P	No. 5 PAE 1	No. 5 PAE 2	No. 5C
7-Day Expansion, per cent																	
Avg.	0.043	0.028	0.027	0.026	0.028	0.036	0.020	0.039	0.008	0.025	0.038	0.026	0.018	0.014	0.014	0.015	0.014
Max.	0.053	0.033	0.032	0.034	0.034	0.041	0.024	0.057	0.012	0.028	0.043	0.031	0.024	0.018	0.021	0.020	0.017
Min.	0.032	0.021	0.022	0.016	0.017	0.027	0.013	0.030	0.002	0.021	0.027	0.016	0.014	0.010	0.009	0.011	0.012
14-Day Expansion, per cent																	
Avg.	0.066	0.039	0.038	0.038	0.039	0.048	0.027	0.060	0.010	0.033	0.051	0.037	0.025	0.019	0.019	0.020	0.020
Max.	0.082	0.046	0.046	0.047	0.047	0.056	0.033	0.086	0.014	0.037	0.060	0.043	0.029	0.023	0.023	0.023	0.026
Min.	0.053	0.031	0.031	0.025	0.027	0.038	0.019	0.049	0.005	0.030	0.040	0.024	0.018	0.015	0.012	0.013	0.017
21-Day Expansion, per cent																	
Avg.	0.090	0.048	0.046	0.046	0.048	0.058	0.033	0.076	0.013	0.038	0.061	0.044	0.030	0.023	0.023	0.023	0.023
Max.	0.119	0.054	0.055	0.056	0.057	0.067	0.041	0.112	0.016	0.042	0.068	0.050	0.034	0.027	0.030	0.028	0.029
Min.	0.072	0.040	0.038	0.032	0.033	0.050	0.024	0.063	0.007	0.034	0.050	0.033	0.023	0.018	0.018	0.018	0.018
28-Day Expansion, per cent																	
Avg.	0.117	0.054	0.052	0.053	0.054	0.066	0.038	0.092	0.014	0.042	0.068	0.049	0.033	0.025	0.025	0.025	0.026
Max.	0.163	0.062	0.062	0.064	0.064	0.074	0.050	0.141	0.019	0.047	0.080	0.060	0.040	0.029	0.032	0.032	0.033
Min.	0.091	0.045	0.046	0.037	0.040	0.059	0.030	0.078	0.009	0.036	0.056	0.037	0.026	0.021	0.017	0.017	0.022
3-Month Expansion, per cent																	
Avg.	0.177	0.091	0.083	0.084	0.087	0.107	0.059	0.279	0.019	0.063	0.101	0.071	0.049	0.035	0.035	0.035	0.040
Max.	0.227	0.105	0.099	0.103	0.104	0.126	0.080	0.701	0.024	0.069	0.116	0.088	0.056	0.040	0.054	0.042	0.047
Min.	0.071	0.082	0.075	0.070	0.073	0.098	0.046	0.207	0.011	0.053	0.081	0.053	0.040	0.030	0.029	0.030	0.032
1-Yr Expansion, per cent																	
Avg.	0.216	0.166	0.144	0.146	0.148	0.225	0.093	0.353	0.029	0.099	0.124	0.112	0.079	0.051	0.053	0.051	0.067
Max.	0.667	0.209	0.172	0.175	0.187	0.287	0.135	1.091	0.043	0.115	0.153	0.133	0.097	0.066	0.081	0.068	0.084
Min.	0.075	0.133	0.125	0.113	0.122	0.175	0.068	0.217	0.021	0.083	0.099	0.090	0.062	0.040	0.036	0.034	0.045

may further improve the test. In the current series of tests, the specimens were cured in the molds stored in the moist closet for 24 ± ½ hr after molding. They were then removed from the molds, properly identified, measured, and placed in water storage. It is probable that moist rooms are not all maintained at the same relative humidity. Furthermore, in the process of removing the specimens from the molds there would be some evaporation of moisture from the specimens. This combination of circumstances would cause some variation in the degree of saturation and the temperature of the specimens and thereby affect the length of the specimens at the time of the initial length measurement. In the proposed method of test, given in the Appendix, it is required that the specimens shall be removed from the molds at the age of 22 to 23 hr. They shall then be properly identified and stored in water at 23.0 ± 1.7 C (73.4 ± 3 F) and allowed to remain in the water at least 30 min prior to making the initial length measurement which shall be made at the age of 24 ± ¼ hr from the time the cement and water are mixed together.

The data shown in Table III and Figs. 1 and 2 indicate the following characteristics of the method of test: (1) significant expansions occur within 28 days, (2) reproducible results can be obtained in different laboratories, and (3) the expansions obtained discriminate between different cements.

The reproducibility of results obtained by different laboratories, or for individual specimens within a laboratory, is far better for this method of test than were the results obtained in previous cooperative tests (**3,4**), using lean mortar bars immersed in sulfate solutions, or using the sulfate susceptibility test.

Effect of Air-Entrainment on Expansion.

As stated previously, two of the cements were used with an air-entraining agent added at the mixer to produce air-entrained mortars. With each cement, the air-entraining agent was added in the quantity required to produce air contents of 10 to 12 per cent and 18 to 20 per cent in the 1:4 standard Ottawa sand mortar, ASTM Method C 185. The effect of entrained air on the expansion of the mortar specimens is shown in Table IV using the average value of expansion for all participating laboratories, Table III.

The results show that air-entrainment has no significant effect on the expansion of the mortar specimens used in this test. These results need not in any way discredit the test as a means of determining the potential sulfate resistance of portland cements. It is well recognized that the water-cement ratio and other characteristics of concretes have a significant effect on their sulfate resistance. Likewise the improved sulfate resistance of the concrete that may be obtained by air-entrainment can be considered as a beneficial property of the concrete over that obtained by the potential resistance of the cement.

Laboratory Tests of 38 Cements

Table V shows the results obtained by the laboratory tests of the 38 cements used in these studies. The table shows the expansions obtained at ages of 7, 14, 21, and 28 days, 3 months, and 1 yr. The cements are arranged in groups according to ASTM types. Air-entraining cements are identified in this report by the letter T as for example 11T. The expansion values shown for cement numbers identified by an asterisk represent the average expansions obtained by the thirteen participating laboratories. The expansion values for the remaining cements are values obtained by one

TABLE IV.—EFFECT OF ENTRAINED AIR ON THE EXPANSION OF MORTAR PRISMS.

Cement	Air Content of 1:4 Mortar, per cent	Expansion of 1 : 2.75 Mortar Prisms at Age Indicated, per cent					
		7 days	14 days	21 days	28 days	3 months	1 yr
No. 21	6.1	0.027	0.038	0.046	0.052	0.083	0.144
No. 21A-E1	10.8	0.026	0.038	0.046	0.053	0.084	0.146
No. 21A-E2	18.1	0.028	0.039	0.048	0.054	0.087	0.148
No. 5P	10.0	0.014	0.019	0.023	0.025	0.035	0.051
No. 5PA-E1	11.6	0.014	0.019	0.022	0.025	0.035	0.053
No. 5PA-E2	18.4	0.015	0.020	0.023	0.025	0.035	0.051

TABLE V.—EXPANSION OF MORTAR PRISMS AT VARIOUS AGES.

Cement	Expansion, per cent					
	7 days	14 days	21 days	28 days	84 days	1 yr
Type I Cement						
No. 11	0.045	0.067	0.085	0.102	0.222	0.645
No. 11T	0.055	0.081	0.103	0.123	0.338	0.359
No. 12	0.058	0.088	0.114	0.135	0.329	0.733
No. 12T	0.070	0.108	0.139	0.166	0.425	1.15
No. 13	0.027	0.042	0.052	0.060	0.104	0.375
No. 14[a]	0.028	0.039	0.048	0.054	0.091	0.166
No. 15[a]	0.043	0.066	0.090	0.117	0.177	0.216
No. 16	0.030	0.044	0.054	0.062	0.103	0.216
No. 16T	0.033	0.047	0.057	0.065	0.106	0.192
No. 17	0.039	0.048	0.062	0.072	0.137	0.325
No. 18	0.085	0.135	0.180	0.224	0.741	...[b]
No. 18T	0.093	0.146	0.191	0.235	1.295	...[b]
Type II Cement						
No. 21[a]	0.027	0.038	0.046	0.052	0.083	0.144
No. 21T	0.035	0.049	0.058	0.065	0.093	0.162
No. 22[a]	0.036	0.048	0.058	0.066	0.107	0.225
No. 23[a]	0.020	0.027	0.033	0.038	0.059	0.093
No. 24	0.017	0.023	0.027	0.030	0.043	0.081
No. 25	0.030	0.040	0.047	0.052	0.075	0.121
No. 2-I	0.037	0.050	0.060	0.068	0.111	0.173
No. 2-L	0.032	0.043	0.051	0.056	0.081	0.139
No. 2-M	0.030	0.038	0.042	0.046	0.062	0.084
No. 2-S	0.026	0.034	0.038	0.042	0.060	0.101
Type III Cement						
No. 31[a]	0.039	0.060	0.076	0.092	0.279	0.353
No. 33	0.039	0.060	0.076	0.093	0.240	0.253
No. 33T	0.051	0.075	0.096	0.116	0.258	0.255
No. 34	0.025	0.033	0.038	0.043	0.066	0.167
No. 3-L[a]	0.008	0.010	0.013	0.014	0.019	0.029
Type IV Cement						
No. 41[a]	0.025	0.033	0.038	0.042	0.063	0.114
No. 42	0.022	0.030	0.035	0.040	0.057	0.089
No. 43[a]	0.038	0.051	0.061	0.068	0.100	0.124
No. 43A[a]	0.026	0.037	0.044	0.049	0.071	0.112
Type V Cement						
No. 51[a]	0.018	0.025	0.030	0.033	0.049	0.086
No. 5-I	0.026	0.034	0.039	0.044	0.062	0.093
No. 5-L	0.018	0.026	0.030	0.032	0.043	0.092
No. 5-M	0.033	0.041	0.046	0.050	0.066	0.089
No. 5-P[a]	0.014	0.019	0.023	0.025	0.035	0.051
No. 5-O[a]	0.014	0.020	0.023	0.026	0.040	0.067
No. 5-S	0.027	0.035	0.039	0.043	0.057	0.081

[a] Values are the average of tests by 13 laboratories.
[b] Discarded.

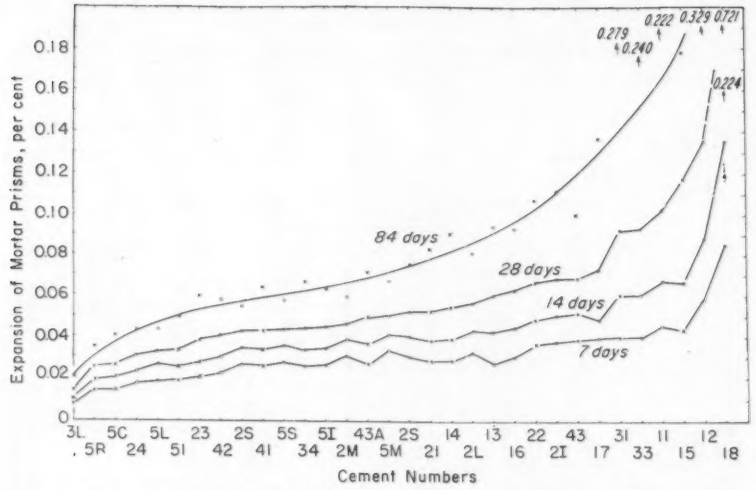

Fig. 3.—Expansion of Mortar Prisms at Various Ages; Cements Arranged in Order of Ascending Expansion at 28 Days.

laboratory, the Portland Cement Assn. Figure 3 shows the expansions obtained with the mortar bar test at ages of 7, 14, 28, and 84 days for the 32 nonair-entraining cements. In this figure the cements are arranged in the order of ascending expansion at 28 days. The relative expansions at other ages are in good agreement with the results at 28 days.

Relationship Between Expansion of Mortar Specimens and C_3A Content of Cement

It is generally recognized that the C_3A content of the cement has a significant effect on sulfate resistance, but it is recognized also that there are some factors other than C_3A that influence the sulfate resistance. For example, it was concluded from the Long-Time Study of Cement Performance in Concrete (2) that:

> While no quantitative relationship between the resistance of the concrete to sulfate attack and C_3A content of the cement was exhibited in these tests, the relationship was such that the percentage of C_3A provides a fairly good criterion of sulfate resistance. The fact that there are several striking exceptions to the relation between sulfate resistance and the C_3A content indicates that there is some unrecognized factor in the cement composition or in the manufacture of the cements which affects the sulfate resistance.

The C_3A content of the cement also has a significant effect on the expansion of the mortar prisms containing excess gypsum. Although there are variations in the relationship between the C_3A content and the expansion of individual cements, there is a good general relationship between the C_3A content of the cements and the expansions of the mortar prisms as shown in Fig. 4. In this figure the cements are arranged according to their C_3A content in the following groups: 0 to 2, 2 to 4, 4 to 6, 6 to 8, 8 to 10, and 10 to 13 per cent. The average expansions for the cements of each group are shown for ages up to 84 days. These results show that progressively larger expansions occur as the C_3A content of the cements increases.

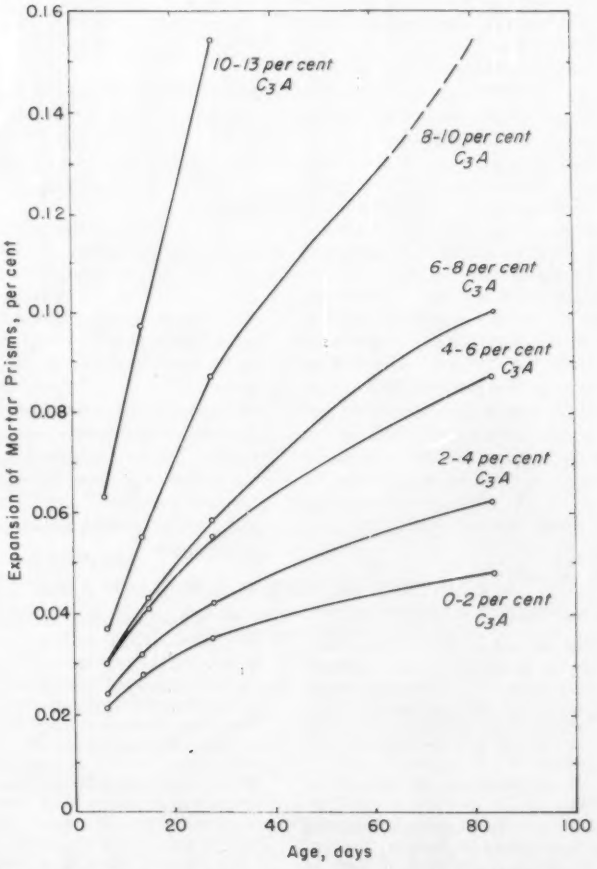

Fig. 4.—Effect of C_3A Content of Cement on the Expansion of Mortar Prisms Containing Excess Gypsum.

Relationships Between Expansion of Mortar Specimens and Field Performance of Concretes

Thirty-five of the 38 cements used in the laboratory tests were used also in concretes exposed to sulfate soils at Sacramento, Calif., as part of the Long-Time Study of Cement Performance in Concrete. Cements No. 3L, 5C, and 5P used in the laboratory tests were not included in the tests of concretes. Twenty-seven of the cements were used in concretes exposed to sulfate soils in 1942. In 1949 concretes prepared using 13 cements were added to this field project. This included repeat tests of 5

cements that had been used in 1942 and 8 new cements.

The concretes prepared from 27 cements, exposed to sulfate soils in 1942, have developed a range of deterioration suitable for showing a relationship between the expansions obtained in the laboratory test and the performance of the cements in concretes. The concrete specimens exposed to sulfate soils in 1949 have shown very little deterioration to date so their sulfate resistance cannot be related to the laboratory test at this time.

Three concrete mixes were used for each of the 27 cements exposed to sulfate soils in 1942. These mixes were designed to have the following cement contents and consistencies within the practical limits of control: mix 1—4 sacks of cement per cu yd having $1\frac{1}{2}$-in. slump; mix 2—5.5 sacks of cement per cu yd having $1\frac{1}{2}$-in. slump; and mix 3—7 sacks of cement per cu yd having $1\frac{1}{2}$-in. slump. An equal number of specimens from each mix were placed in each of two different basins containing natural and prepared sulfate soils. For basin I, natural soil from Willows, Calif., which is high in Na_2SO_4 and low in $MgSO_4$, was used. For basin II, soil of higher $MgSO_4$ content was used.

The specimens were rated on the basis of visible evidence of disintegration. By this procedure, numerical ratings were assigned ranging from 1 for unaffected specimens to 6 for those completely broken down. The specimens were inspected and rated three times a year for the first two years and once a year thereafter. A numerical value for the sulfate resistance of concrete made with any one cement was obtained by using the average cumulative value of the ratings of specimens made with the cement. The ratings reported at each inspection, for one concrete mix in one basin, were added, and the sum thus obtained divided by the number of ratings provided a rating for the cement in that particular mix for that basin. The average of the ratings for the three different mixes provides a grand average numerical value for the sulfate resistance of the cement in that basin. Table VI shows the sulfate resistance of concretes prepared for the 27 different cements analyzed in this manner.

TABLE VI.—SULFATE RESISTANCE RATINGS OF CONCRETES MADE FROM 27 DIFFERENT CEMENTS.

Numerical ratings range from 1 for unaffected specimens to 6 for those completely broken down.

Cement	Ratings							
	Basin I				Basin II			
	Cement Content, sacks per cu yd				Cement Content, sacks per cu yd			
	4.0 sacks	5.5 sacks	7.0 sacks	Grand Average	4.0 sacks	5.5 sacks	7.0 sacks	Grand Average
PORTLAND CEMENTS								
No. 11	5.9	5.1	1.4	4.1	5.1	4.1	1.9	3.7
No. 12	5.7	5.2	2.4	4.4	5.1	4.1	1.8	3.7
No. 13	5.6	5.0	1.5	4.0	4.3	2.7	1.6	2.9
No. 14	5.5	4.4	1.5	3.8	4.0	2.1	1.4	2.5
No. 15	5.9	4.5	2.2	4.2	5.1	4.1	1.9	3.7
No. 16	5.5	4.5	2.2	4.0	3.0	2.2	1.8	2.3
No. 17	5.6	4.7	2.3	4.2	4.0	2.8	1.9	2.9
No. 18	5.8	5.2	3.3	4.8	5.3	4.7	3.1	4.4
No. 21	5.1	3.4	1.3	3.3	3.1	1.8	1.4	2.1
No. 22	5.5	4.9	1.4	3.9	4.0	2.3	1.6	2.6
No. 23	5.1	3.5	1.2	3.3	2.4	1.7	1.4	1.8
No. 24	5.4	3.3	1.2	3.3	2.8	1.9	1.4	2.0
No. 25	5.4	3.6	1.3	3.4	2.9	1.9	1.4	2.1
No. 31	5.7	4.4	2.2	4.1	4.3	2.6	2.1	3.0
No. 33	5.9	4.6	2.1	4.2	4.4	2.4	2.0	2.9
No. 34	5.4	3.9	1.6	3.6	2.3	2.0	1.6	2.0
No. 41	4.7	3.3	1.4	3.1	3.0	1.9	1.4	2.1
No. 42	4.0	2.7	1.4	2.7	2.9	1.9	1.5	2.1
No. 43	4.6	3.2	1.3	3.0	2.6	1.7	1.4	1.9
No. 43A	4.7	2.4	1.2	2.8	2.9	1.9	1.4	2.1
No. 51	4.7	2.3	1.3	2.8	2.8	1.9	1.4	2.0
AIR-ENTRAINING PORTLAND CEMENTS								
No. 11T	5.4	4.7	1.3	3.8	4.0	2.7	1.7	2.8
No. 12T	5.6	4.9	2.3	4.3	4.9	4.1	2.4	3.8
No. 16T	4.3	1.4	1.2	2.3	2.6	1.7	1.5	1.9
No. 18T	5.4	5.0	2.9	4.4	5.1	4.5	2.9	4.2
No. 21T	4.0	1.4	1.2	2.5	3.0	1.6	1.3	2.2
No. 33T	5.2	4.8	1.4	3.8	3.2	2.0	1.4	2.2

Figure 5 shows the relationship between the expansion of mortar prisms and the sulfate resistance of concretes made with the 27 different cements. The cements are arranged in the order of ascending expansion of the mortar bars at 28 days as shown in the lower diagram. The 21 portland cements are shown at the left in this figure and the six air-entraining cements are shown at the right. The two middle diagrams show the sulfate resistance rating of concrete specimens exposed to different sulfate soils, basins I and II, respectively. The top diagram shows the combined rating of the concretes, that is, the average for basins I and II. Figure 6 shows some of the same data plotted in a different manner to show the relationship between the sulfate resistance of the concretes and the expansion of the mortar prisms. In this figure the cements are arranged in the order of ascending combined rating of the concretes in basins I and II as shown in the lower diagram, and the 28-day expansions of the mortar prisms are shown in the upper diagram. Figures 5 and 6 show a relatively good relationship between the 28-day expansions of the mortar prisms and the sulfate resistance of the concretes; that is, as the expansions of the mortar prisms increase, the sulfate resistance of the concretes decreases.

APPENDIX

A METHOD OF TEST FOR SULFATE RESISTANCE OF PORTLAND CEMENTS

Scope

1. This method of test is intended to determine the potential sulfate resistance of portland cement by measuring the expansion of mortar bars containing excess calcium sulfate, equivalent to a total SO_3 content of 7.0 per cent by weight of the cement.

Apparatus

2. (*a*) *Scales and Weights,* conforming to the requirements of Section 2(*a*) and (*b*) of the Standard Method of Test for Compressive Strength of Hydraulic Mortars (C 109).[3]

(*b*) *Glass Graduates,* 250-ml capacities, with graduations at 2-ml intervals, for measuring the mixing water, made to deliver the indicated volume at 20 C (68 F). The permissible variation shall be ± 2 ml. The main graduation lines shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around the cylinder and intermediate graduations shall extend at least one fifth of the way around. Subdivisions may be omitted for the lowest 10 ml.

(*c*) *Tamper,* made of a nonabsorptive, nonabrasive material such as medium-hard rubber or seasoned oak wood rendered nonabsorptive by immersion for 15 min in paraffin at approximately 200 C (392 F) and having a cross-section of $\frac{1}{2}$ by 1 in., and a convenient length (5 or 6 in.). The tamping face shall be flat and at right angles to the length of the tamper.

(*d*) *Trowel,* with steel blade 4 to 6 in. in length, with straight edges.

(*e*) *Mixer, Bowl, and Paddle,* conforming to the requirements of Section 2 of the Tentative Method for Mechanical Mixing of Hydraulic Cement Mortars of Plastic Consistency (C 305).[3]

(*f*) *Molds,* conforming to the requirements of Section 2(*c*) of the Standard

Method of Test for Autoclave Expansion of Portland Cement (C 151).[3]

(*g*) *Length Comparator,* for measuring the length of the mortar bars, shall conform to the requirements of Section 2(*f*) of the Standard Method of Test for Autoclave Expansion of Portland Cement (C 151).[3]

Conditions

3. The temperature of the air in the vicinity of the mixing slab, the dry materials, molds, base plates, and mixing bowl, shall be maintained between 20 and 27.5 C (68 and 81.5 F). The temperature of the mixing water, moist closet or moist room, and water in the storage tank shall not vary from 23 C (73.4 F) by more than ± 1.7 C (3 F). The moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 90 per cent.

Graded Standard Sand

4. The sand used for making test specimens shall be natural silica sand from Ottawa, Ill., graded as follows:

Sieve[a]	Percentage Retained
No. 100	98 ± 2
No. 50	72 ± 5
No. 30	2 ± 2
No. 16	None

[a] Conforming to Standard Specifications for Sieves for Testing Purposes (E 11).[3]

Molding Plaster

5. The molding plaster to be added to provide the excess calcium sulfate shall conform to the requirements of the Standard Specifications for Gypsum Molding Plaster (C 59).[3]

Number of Specimens

6. Six test specimens, three from each of two batches, shall be made for each cement.

Preparing Specimen Molds

7. Thinly cover the molds with mineral oil; set the stainless steel or noncorroding metal reference points taking care to keep them clean and free of oil. Heat a mixture of 3 parts of paraffin to 5 parts of rosin by weight to 110 to 120 C (230 to 248 F) and apply to the outside contact lines of the molds making them watertight.

Proportioning

8. (*a*) The percentage of cement and gypsum molding plaster required to provide a mixture containing 7.0 per cent SO_3 by weight shall be calculated as follows:

$$\text{Cement, per cent} = \frac{(g - x)}{g - c} 100$$

$$\text{Gypsum molding plaster, per cent} = \frac{(x - c)}{g - c} 100$$

where:

c = per cent SO_3 in cement,
g = per cent SO_3 in gypsum molding plaster, and
x = desired SO_3 − 7.0 per cent.

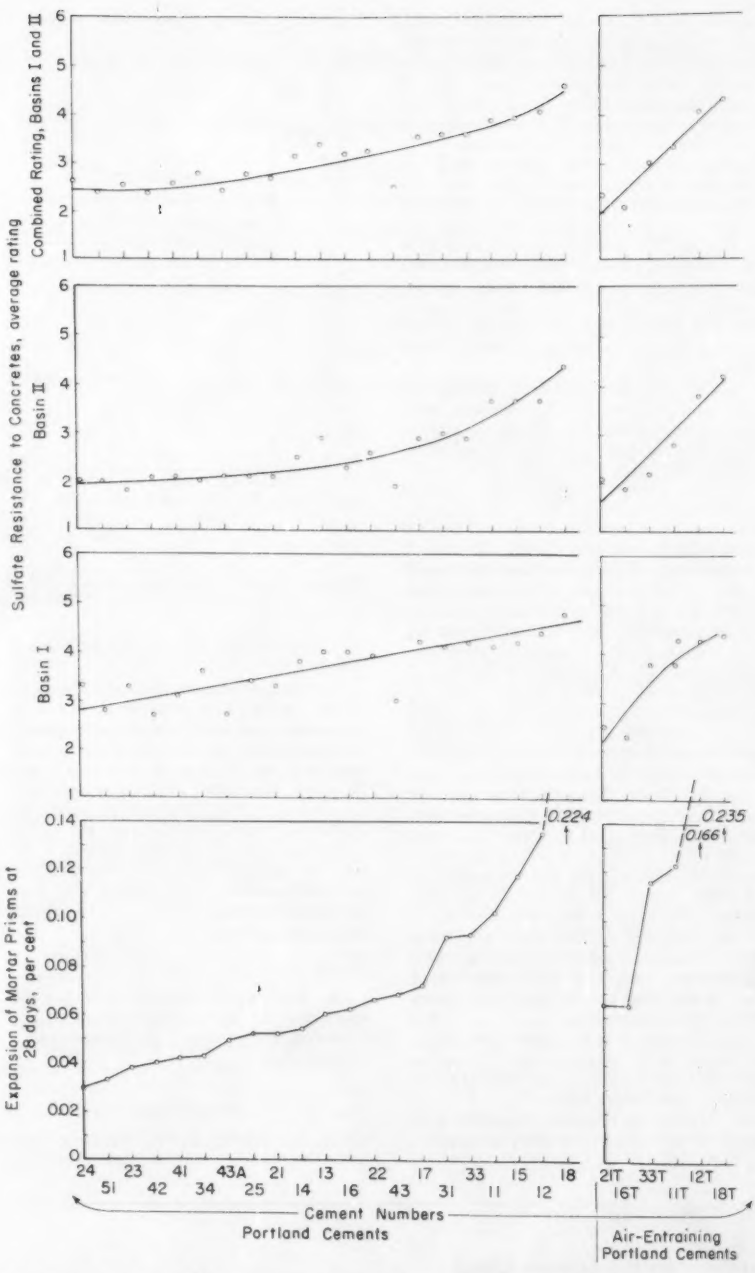
Sulfate Resistance to Concretes, average rating
Combined Rating, Basins I and II
Basin II
Basin I
Expansion of Mortar Prisms at 28 days, per cent
0.224
0.235
0.166
24 23 41 43A 21 13 22 17 33 15 18 21T 33T 12T
51 42 34 25 14 16 43 31 11 12 16T 11T 18T
Cement Numbers
Portland Cements
Air-Entraining Portland Cements

Fig. 5.—Expansion of Mortar Prisms *versus* Sulfate Resistance of Concretes in Order of Ascending Expansion of the Mortar Bars.

(*b*) The combined proportions of dry materials to be mixed at one time shall be 400 g of cement and gypsum molding plaster combined and 1100 g of graded standard sand. The quantity of mixing water shall be as follows:

For types I, II, IV, and V cements	216 ml
For types IA, IIA cements	208 ml
For type III cement	224 ml
For type IIIA cement	216 ml

Procedure

9. (*a*) Prehydrate the molding plaster for at least 60 min before incorporating it in the mix to avoid premature stiffening of the mortar; place 150 ml of water in a 250 ml beaker, add the required amount of molding plaster, and stir occasionally with a glass rod protected with a rubber policeman. The slurry becomes creamy about 35 min after the plaster is added to

the water. Particular attention to stirring is required at this time to prevent setting and the formation of lumps in the slurry. With additional stirring the slurry again becomes more fluid. Keep the beaker covered as much as possible to prevent loss of water by evaporation. Following hydration the plaster shall be transferred to the mixing bowl and the remaining mixing water used to wash the slurry from the beaker into the bowl.

(*b*) Mix the cement, prehydrated gypsum molding plaster, and graded standard sand in accordance with procedure described in Section 5 of the Tentative Method for Mechanical Mixing of Hydraulic Cement Mortars of Plastic Consistency (C 305).[3]

(*c*) Immediately following mixing, fill the mold in two layers; compact each layer with the tamper. Work the mortar into the corners, around the reference points, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut the mortar off flush with the top of the mold and smooth the surface with a few strokes of the trowel.

(*d*) *Initial Storage.*—Cure the specimens in the molds in the moist closet at 23 ± 1.7 C (73.4 ± 3 F) for 22 to 23 hr. They shall then be removed from the molds, properly identified, and then placed in water at 23 ± 1.7 C (73.4 ± 3 F) for at least 30 min prior to making the initial length measurement which shall be made at the age of 24 ± ¼ hr from the time the cement and water are mixed together.

(*e*) *Subsequent Storage.*—After the bars have been removed from the molds and measured, they shall be stored in water at 23 ± 1.7 C (73.4 ± 3 F). Store the specimens with at least ¼-in. clearance on all sides except for the necessary supports. The ratio of the volume of water to the volume of the bars shall not exceed 5 to 1 to prevent excessive leaching. Replenish the water with fresh water every 7 days for the first 28 days and every 28-day period thereafter.

(*f*) Measure the specimens for length by means of the comparator described in ASTM Method C 151.[3] Wipe the bars with a damp cloth before measuring. If more than one bar is removed from the container at one time, they shall be covered with a damp cloth to prevent evaporation of water.

(*g*) The first measurement shall be made at the age of 24 ± ¼ hr from the time the cement and water are mixed together. Additional readings shall be made at total ages of 7, 14, 21, and 28 days and every 28 days thereafter until the tests are terminated. The difference in length of specimens, when removed from the molds at one day and at any subsequent period, shall be calculated to the nearest 0.01 per cent of the effective gage length, and shall be recorded as the expansion of the specimen at that period.

Report

10. The average expansion of the six specimens of a given cement shall be reported as the expansion of the cement at a given period.

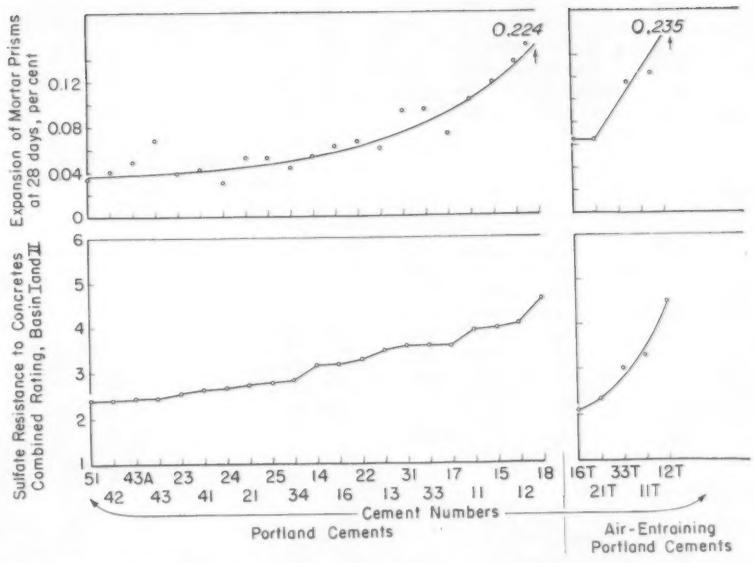

Fig. 6.—Sulfate Resistance of Concretes *versus* Expansion of Mortar Prisms in Order of Ascending Combined Visible Disintegration Rating of the Concretes.

References

(1) D. G. Miller, P. W. Manson, and R. T. H. Chen, "Bibliography on Sulfate Resistance of Portland Cements," Concretes and Mortars, Paper No. 708, Miscellaneous Journal Series, University of Minnesota. (1952)

(2) F. R. McMillan, T. E. Stanton, I. L. Tyler, and W. C. Hansen, "Long-Time Study of Cement Performance in Concrete—Chapter 5. Concrete Exposed to Sulfate Soils," Special Publication of the American Concrete Inst., (1949); *Bulletin No. 30*, Research Laboratories of the Portland Cement Assn. (1949).

(3) "Report of the Working Committee on Sulfate Resistance," Appendix II, Report of Committee C-1, *Proceedings*, Am. Soc. Testing Mats., Vol. 46, p. 278 (1946).

(4) David Wolochow, "Determination of the Sulfate Resistance of Portland Cement," Appendix, Report of Committee C-1, *Proceedings*, Am. Soc Testing Mats., Vol. 52, p. 250 (1952)

Standards for Biochemicals Urged

Replies to questionnaires sent out by the National Research Council to the Division of Biological Chemistry of the American Chemical Society and the American Society of Biological Chemists indicated a pressing need for a broad program to establish minimum standard specifications for commercial biochemicals. Of the 922 replies received, about 90 per cent were in favor of such action.

Categories of biochemicals mentioned more than 100 times each in the replies were: nucleic acid, amino acids and peptides, coenzymes, enzymes, lipids, and carbohydrates. Experience in the standardization of related materials such as reagent chemicals by the American Chemical Society and also with the U. S. Pharmacopeia and National Formulary indicates that an undertaking to standardize biochemicals would necessarily be a long-term effort and no immediate benefit could be expected.

This effort is under the aegis of the Committee on Biological Chemistry, Division of Chemistry and Chemical Technology of the National Research Council. Committees are currently being organized by the NRC in order to carry out this standardization work. Funds for this undertaking are being provided partly by a grant from the National Institute of Health and a Rockefeller Public Service Award to Sam R. Hall, executive secretary of the endocrinology study section of the NIH.

A more complete account of this activity may be found in the January 16, 1956 issue of *Chemical and Engineering News*.

Fluorescent Sunlamps in Laboratory Aging Tests for Plastics

By Frank W. Reinhart and Mary K. Mutchler

The fluorescent sunlamp offers these advantages over the S-1 sunlamp: it is cheaper; it can be used for a longer period; it does not require the use of a special fixture; the temperature of the test specimens can be controlled more readily because of low output; larger areas of material can be exposed; tested areas are more uniformly radiated and deteriorated.

THE laboratory aging (accelerated weathering) test for plastics based on work by Kline, Crouse, and Axilrod[1] and described in Method 6021 of Federal Specification L-P-406[2] calls for cyclic exposure of specimens to fog and radiant energy from an S-1 sunlamp. Although the S-1 bulb provides a good source of ultraviolet radiant energy, it has several disadvantages for use in laboratory aging tests. The bulb is expensive and has a short life—less than 550 hr for this application. Only small specimens can be exposed because of the geometry of the bulb. The radiant energy output is high in the visible and infrared ranges; this makes it difficult to control the temperature of the specimens at the required temperature of 55 to 60 C. The lamp operates on an autotransformer that is obsolete and is difficult to replace. The transformers burn out after about 2 yr of continuous operation.

An attempt to test square-yard pieces of plastic and rubber coated fabrics instead of the usual 1.5 by 2.7-in. specimens with a modification of the S-1 sunlamp test[2] led to unsatisfactory results. Nine lamps were spaced uniformly over the test area and the specimen was moved during exposure to the ultraviolet radiant energy in a planar rotary manner to obtain uniform exposure. Large blowers were used to cool the specimen. When conditions were such that sufficient radiant energy to obtain accelerated deterioration was observed, the temperature of the specimen was higher than the desired temperature of 55 to 60 C and was not uniform over the surface. The specimen usually developed a cracked melted appearance not typical of that observed in exposure outdoors. The results indicated the need for a source of ultraviolet radiant energy that does not generate a large amount of heat.

The RS sunlamp bulb had been tried as a replacement for the S-1 sunlamp bulb, but the results obtained in the tests with a variety of plastic materials were not satisfactory.

The fluorescent sunlamp bulb appeared promising for the following reasons: (*a*) specimens with a large area can be exposed to uniform radiation; (*b*) the heat output is very low, making it relatively easy to control the temperature; (*c*) it can be used with standard fluorescent lamp fixtures; (*d*) the cost is not high; (*e*) the useful life of the lamp is much longer than that of the S-1 bulb.

Tests of a variety of plastic materials were made with Method 6021, modified by using fluorescent sunlamps in place of the S-1 sunlamps, and with natural aging when exposed outdoors. The results are described and discussed in this report. This investigation was supported in part by the Chemicals and Plastics Division, Research and Development Branch, Office of the Quartermaster General, Department of the Army. The assistance of the members of the staff of that agency and of the National Bureau of Standards is gratefully acknowledged. The spectral output of the fluorescent sunlamp in Fig. 1 was supplied by Ralph Stair of this Bureau.

Description of Fluorescent Sunlamp

The lamp used in the tests described is a Westinghouse fluorescent sunlamp F20 T12. It resembles the usual fluorescent bulb in appearance, is 24 in. long, has an input of 20 w, and fits into standard fluorescent lamp fixtures. The spectral output is shown in Fig. 1. This spectrum is the average of measurements obtained with several of these lamps. It agrees with the spectrum shown in a description of the fluorescent sunlamp by Sheetz.[3] The same type of fluorescent sunlamp is also available in a 40-w size, which is 4 ft long. The fluorescent sunlamps were conditioned by burning for 100 hr before use in a test. Lamps that had burned for 1500 hr were discarded. Tests are under way to determine whether or not these lamps can be used for a longer period.

The S-1 sunlamp is described in earlier papers.[4,5] The radiant energy

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] G. M. Kline, W. A. Crouse, and B. M. Axilrod, "Accelerated Weathering of Transparent Plastics," *Proceedings*, Am. Soc. Testing Mats., Vol. 40, p. 1256 (1940).

[2] Federal Specification L-P-406b for Plastics, Organic: General Specifications, Test Methods, Federal Standard Stock Catalog, Section IV, Part 5, Item L-P-406b, September 27, 1951, and Amendment-1, September 25, 1952.

[3] R. S. Sheetz, "Sunlight from Electricity," *Westinghouse Engineer*, Vol. 9, Nov., 1949, pp. 170–173.

[4] N. T. Gordon and F. Benford, "Ultraviolet from the Sun and from General Electric Sunlamps," *General Electric Review*, Vol. 33, May, 1930, pp. 283–295.

[5] W. E. Forsythe, B. T. Barnes, and M. A. Easley, "Characteristics of the New General Electric Sunlamp," *General Electric Review*, Vol. 33, June, 1930, pp. 358–365.

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MARY K. MUTCHLER, Chemist, Plastics Section, National Bureau of Standards, has been engaged in research pertaining to the development of test methods for determining the properties of plastics.

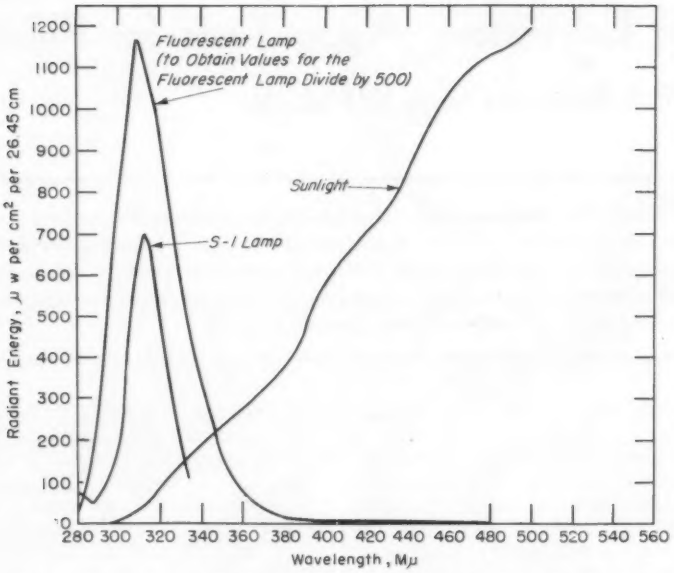

Fig. 1.—Comparison of Radiant Energy Output from Sunlight, S-1 Sunlamp, and Fluorescent Lamp.

outputs of the S-1 sunlamp and sunlight at noon in July on a clear day in Washington, D. C., are also shown in Fig. 1. Comparative output characteristics of the S-1 and RS sunlamp bulbs are given in a bulletin issued by General Electric Co.[6]

S-1 Sunlamp Test Procedure

The basic procedure used was the cyclic sunlamp-fog laboratory aging (accelerated weathering) Test Method 6021 in Federal Specification L-P-406.[2] The 24-hr cycle consists of 2-hr exposure to fog, 2-hr exposure to the radiant energy from an S-1 sunlamp, 2-hr exposure to fog, and 18-hr exposure to the radiant energy. The specimens are mounted on a turntable rotating at 33 rpm. The tests were made in a room with circulating air controlled at 23 ± 1 C and 50 ± 2 per cent relative humidity. The temperature of the specimens was controlled at 55 to 60 C. Calculations show that the relative humidity of the air at the hot face of the specimens is between 6 and 8 per cent. Ten of these cycles have approximately the same effect on plastic materials as exposure outdoors for 12 ± 6 months in Washington, D. C., at 45 deg facing south.

This method using the S-1 sunlamp bulb was used as the control since extensive experience with this method and outdoor exposure in Washington, D. C., at 45 deg facing south has shown good correlation for more than 90 per cent of the many plastics and resinous materials tested. Most of the materials that have not given comparable results are vinyl chloride plastics. Much better correlation is obtained with these plastics if the distance between the bottom of the S-1 sunlamp bulb and the plane of the specimens is 7 in. instead of the 6 in. called for in Method 6021. The tests of vinyl chloride plastics reported here were made at the 7-in. distance as noted in the tables.

Outdoor Exposure Tests

Specimens of some of the materials were exposed outdoors in Washington, D. C., at an angle of 45 deg facing south as noted in the tables for comparison with specimens of the same materials exposed in the S-1 and fluorescent sunlamp laboratory aging tests.

Fluorescent Sunlamp Test Procedure

The fluorescent sunlamp test procedure is similar to the S-1 sunlamp procedure except as follows: Five fluorescent sunlamp bulbs are used instead of the S-1 sunlamp. They are located 3 in. above the plane of the specimens on the rotating turntable, parallel, and 2 $\frac{5}{16}$ in. between centers. The equipment is enclosed in a cabinet with electric heaters, relays, blowers, and controls set to circulate air at approximately 60 C over the specimens.

[6] *Mercury Lamps*, bulletin issued by the General Electric Co., Engineering Div., Lamp Dept., Cleveland, Ohio.

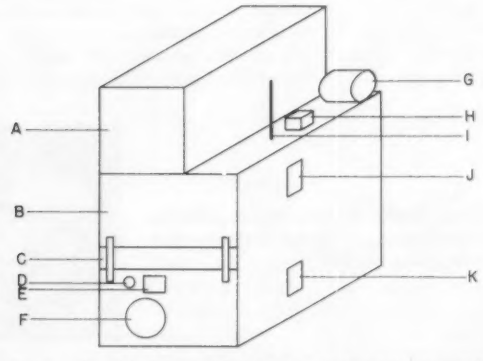

Fig. 2.—Outside View of Laboratory Aging (Accelerated Weathering) Box.

A—Heat Chamber
B—Exposure Chamber
C—Sliding Door
D—Voltmeter
E—Turntable Switch
F—Variac
G—Fan Motor
H—Thermostat
I—Thermometer
J—Light Switch
K—Main Switch

½ in. = 1 ft.

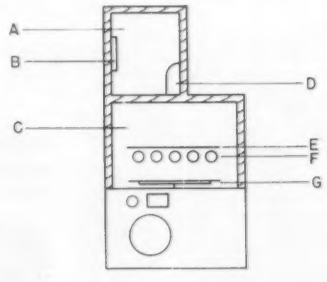

Fig. 3.—Front View Showing Inside of Heat Chamber and Exposure Chamber.

A—Heat Chamber
B—Electric Heater
C—Exposure Chamber
D—Fan
E—Metal Reflector
F—Fluorescent Bulbs
G—Turntable

½ in. = 1 ft.

Since the air supply was taken from a room controlled at 23 ± 1 C and 50 ± 2 per cent relative humidity, the relative humidity of the air at 60 C is between 6 and 8 per cent. Sketches of this apparatus are shown in Figs. 2 and 3.

This procedure was selected after trials of several other conditions. Using three instead of five fluorescent sunlamps, 6 in. above the specimens and no enclosure, the effects on the specimens were much less severe than those produced with the S-1 sunlamp. The temperature of the specimens was only 23 C with the fluorescent sunlamps compared with 60 C with the S-1 sunlamp. When the apparatus was enclosed in a cabinet and the circulating air maintained at 60 C, the three fluorescent sunlamps at the 6-in. distance produced effects that were still less severe than those produced by the S-1 sunlamp. Reducing the distance between the lamps and the specimens to 3 in. and maintaining a temperature of 60 C gave results closer to those obtained with the S-1 sunlamp but still somewhat less severe. Increasing the number of fluorescent sunlamps to 5 gave the results presented in this report.

All the tests were made in a room with circulating air controlled at 23 ± 1 C and 50 ± 2 per cent relative humidity. Two pieces of equipment with S-1 sunlamps and two with fluorescent sunlamps were used to obtain check results.

Materials

The plastic materials used in the tests included samples of transparent plastics, molded translucent and opaque sheets, laminates, upholstery, reinforced flexible glazing, and flexible automotive glazing. The types of plastics include phenolic, melamine, ethyl cellulose, cellulose acetate, cellulose nitrate, cellulose propionate, vinyl chloride, vinyl chloride acetate, polyester, styrene, methyl methacrylate, modified methyl methacrylate, and methyl alpha-chloroacrylate. The materials are described in Table I.

Results and Discussion

The results obtained when specimens were exposed for 120 and 240 hr in the laboratory aging tests and for various periods outdoors beginning on June 30, 1952, except when otherwise noted, are given in Tables II to VIII and in the following discussion. Changes in appearance and flexibility and measurements of light transmission and haze of the transparent materials are reported. The optical measurements were made

TABLE I.—DESCRIPTION OF MATERIALS.

Sample	Product	Color	Type of Plastic	Nominal Thickness, in.
T1	Transparent sheet	Colorless	Ethyl cellulose	0.030
T2			Cellulose acetate	0.030
T3			Cellulose acetate	0.030
T4			Cellulose nitrate	0.030
T5			Cellulose propionate	0.010
T6			Polyester	0.250
T7			Methyl methacrylate, regular	0.150
T8			Methyl methacrylate, regular	0.150
T9			Methyl methacrylate, heat resistant	0.150
T10			Methyl methacrylate, heat resistant	0.150
T11			Methyl methacrylate, heat resistant UVA	0.215
T12			Modified methyl methacrylate	0.375
T13[a]			Methyl alpha-chloroacrylate	0.125
T14[a]			Methyl alpha-chloroacrylate	0.125
T15[a]			Methyl alpha-chloroacrylate	0.125
T16			Methyl alpha-chloroacrylate	0.187
T17[a]			Methyl alpha-chloroacrylate	0.250
T18[a]			Methyl alpha-chloroacrylate	0.250
T19			Styrene	0.030
M1	Molded sheet, translucent	Red	Ethyl cellulose	0.050
M2	Molded sheet, translucent	Red	Ethyl cellulose	0.100
M3	Molded sheet, opaque	Black	Ethyl cellulose	0.125
M4	Molded sheet, opaque	Pale pink	Vinyl chloride	0.023
M5	Molded sheet, translucent	Pale blue	Vinyl chloride	0.004
L1	Laminate sheet, canvas	Tan	Phenolic	0.062
L2	Laminate sheet, canvas	Brown	Phenolic	0.125
L3	Laminate sheet, canvas	Reddish brown	Phenolic	0.150
L4	Laminate sheet, paper	Green	Phenolic	0.062
L5	Laminate sheet, glass	White	Polyester	0.027
L6	Laminate sheet, glass	Tan	Polyester	0.062
L7	Laminate sheet, glass	Grayish tan	Polyester	0.125
D1	Decorative laminate, table top	Tan, wood grain finish	Melamine	0.066
D2	Decorative laminate, table top	Mahogany	Melamine	0.161
U1	Upholstery, coated fabric sheeting	Red	Vinyl chloride	0.027
U2	Upholstery, coated fabric sheeting	White		0.018
U3	Upholstery, coated fabric sheeting	Blue		0.019
U4	Upholstery, coated fabric sheeting	Red		0.019
U5	Upholstery, coated fabric sheeting	Wine		0.019
U6	Upholstery, coated fabric sheeting	Green		0.020
U7	Upholstery, coated fabric sheeting	Green		0.020
U8	Upholstery, coated fabric sheeting	Navy blue		0.021
R1	Reinforced flexible glazing 4 by 4 cotton mesh	White	Cellulose acetate	0.019
R2	Reinforced flexible glazing 4 by 4 cotton mesh	Green		0.020
R3	Reinforced flexible glazing 4 by 4 iron wire mesh	Colorless		0.022
R4	Reinforced flexible glazing 14 by 13 iron wire mesh	Colorless		0.027
A1	Automotive glazing, flexible	Green	Vinyl chloride	0.040
A2		Green		0.040
A3		Colorless		0.040
A4		Colorless		0.040

[a] These samples were prepared with the same catalyst under different polymerization conditions.

TABLE II.—LIGHT TRANSMISSION IN PER CENT OF TRANSPARENT PLASTICS USED IN LABORATORY AGING AND OUTDOOR EXPOSURE TESTS.

Sample	Number of Specimens Tested	Light Transmission										
		Fluorescent Sunlamp			S-1 Sunlamp			Outdoors[a]				
		Initial	After 120-hr Test	After 240-hr Test	Initial	After 120-hr Test	After 240-hr Test	Initial	After 5 weeks	After 10 weeks	After 28 weeks	After 45 weeks
T1	18	84	74	68	84	81	72	83	84	85	55	[c]
T2	18	90	91	87	90	91	91	88	90	90	90	90
T3	18	91	91	86	91	91	90	...	...	...	...	...
T4	18	88	76	67	88	83	69	...	...	...	...	...
T5	12	91	90	90	91	91	91	89	90	89	[b]	...
T6	3	89	88	88	89	88	88	88	88	88	88	88
T7	3	92	92	92	92	92	92	...	...	...	...	...
T8	3	92	92	92	92	92	92	...	...	...	...	...
T9	3	92	92	92	92	92	92	...	...	...	...	...
T10	3	92	92	92	92	92	92	...	...	...	...	...
T11	3	92	92	92	92	92	92	...	...	...	...	...
T12	3	92	92	92	92	92	92	...	...	...	...	...
T13	1	92	87	86	92	89	88	91	90	90	91	90
T14	1	91	84	83	91	86	85	90	88	87	87	86
T15	1	91	87	86	92	88	88	91	90	89	89	88
T16	1	91	84	84	90	86	86	91	89	88	88	87
T17	1	90	84	83	90	85	85	91	87	86	85	85
T18	1	91	82	82	91	84	84	...	...	...	...	...
T19	18	90	89	88	90	90	89	89	88	86	84	76

[a] Exposed outdoors in Washington, D. C., at 45 deg facing south.
[b] Specimens broke into several pieces after 21 weeks of exposure; the pieces had considerable haze.
[c] Specimens were delaminated.

TABLE III.—HAZE IN PER CENT OF TRANSPARENT PLASTICS USED IN LABORATORY AGING AND OUTDOOR EXPOSURE TESTS.

Sample	Number of Specimens Tested	Haze										
		Fluorescent Sunlamp			S-1 Sunlamp			Outdoors[a]				
		Initial	After 120-hr Test	After 240-hr Test	Initial	After 120-hr Test	After 240-hr Test	Initial	After 5 weeks	After 10 weeks	After 28 weeks	After 45 weeks
T1	18	5.1	41	70	5.5	14.0	54	6.8	7.6	5.3	9.3	[c]
T2	18	2.4	3.5	19	2.5	2.9	5.0	2.1	2.3	3.0	2.8	4.1
T3	18	2.2	2.6	21	1.5	1.7	4.2	...	...	...	...	...
T4	18	3.3	19	60	3.4	5.6	48	...	...	...	...	...
T5	12	3.7	3.6	3.2	3.4	3.4	3.6	3.8	3.1	3.9	[b]	...
T6	3	0.9	1.0	1.2	0.9	1.0	1.0	0.9	1.1	1.0	1.3	1.6
T7	3	0.4	0.7	1.2	0.3	0.8	0.9	...	...	...	...	...
T8	3	0.3	0.8	0.7	0.4	0.7	0.9	...	...	...	...	...
T9	3	0.3	0.8	0.6	0.3	0.7	0.6	...	...	...	...	...
T10	3	0.4	0.8	0.7	0.3	0.5	0.5	...	...	...	...	...
T11	3	0.3	0.3	0.7	0.3	0.5	0.5	...	...	...	...	...
T12	3	0.5	0.8	0.5	0.3	0.8	0.8	...	...	...	...	...
T13	1	0.9	1.0	1.3	0.7	0.7	0.7	0.7	1.1	1.1	1.0	1.3
T14	1	2.4	2.3	2.4	2.4	2.3	2.0	2.6	2.7	2.8	2.3	2.7
T15	1	2.6	2.5	3.3	2.5	2.9	2.5	2.6	2.9	3.1	2.6	2.9
T16	1	0.9	0.9	1.1	1.0	0.9	1.2	0.9	1.3	1.6	1.1	1.5
T17	1	2.4	2.7	2.9	2.6	2.7	3.0	1.4	2.6	3.1	2.4	2.8
T18	1	2.6	2.6	2.4	2.5	2.7	2.8	...	...	...	...	...
T19	18	1.5	3.1	3.6	1.7	2.3	2.9	3.2	6.6	10	16	37

Exposed outdoors in Washington, D. C., at 45 deg facing south.
[b] Specimens broke into several pieces after 21 weeks of exposure; the pieces had considerable haze.
[c] Specimens were delaminated.

in accordance with Method A[7] of ASTM Method of Test D 1003 and Method 3022 in Federal Specification L-P-406.[2]

Transparent Plastics

The results for the transparent plastics, Tables II through V, show reasonably good agreement between the laboratory aging tests with the fluorescent and S-1 sunlamps. The agreement between the laboratory tests and the outdoor exposure tests is also good. No outdoor tests were made with the methyl methacrylate plastics T7 through T12. However, many outdoor exposure tests have been made with these plastics in previous years, and the results of these tests agree very well with the results of the laboratory tests reported herein.

The general type of deterioration appeared to be the same for the various materials submitted to the aging tests. There is some indication that the fluorescent test is somewhat more severe than the S-1 test. The effects produced by the fluorescent sunlamps were more uniform over the surface of the specimen than that produced by the S-1 sunlamp. No significant differences were observed between duplicate sets of specimens tested with the two different fluorescent sunlamp exposure units. There was an observable difference between the duplicate sets of specimens tested with the two different S-1 sunlamps, particularly with the cellulose acetate plastics.

Molded Plastic Sheets

Sample M1 turned orange along one edge in the test with the fluorescent sun-

[7] Standard Method of Test for Haze and Luminous Transmittance of Transparent Plastics (D 1003 – 52), 1955 Book of ASTM Standards, Part 6.

lamp and was slightly faded in both tests. The comparative effects of the two laboratory aging tests on samples M2 and M3 were visually identical. Sample M2 faded slightly and sample M3 was unaffected in appearance in both laboratory tests. Samples M4 and M5 were more severely affected by the test with the fluorescent sunlamp than that with the S-1 sunlamp. The specimens of sample M4 exposed to the fluorescent sunlamp developed a deep mahogany color, whereas those exposed to the S-1 sunlamp became unevenly streaked a dark red color. The specimens of sample M5 exposed to the fluorescent sunlamp turned to a deep tan color, whereas those exposed to the S-1 sunlamp turned yellow. The appearance and flexibility of the specimens of samples M2 to M4 after 45 weeks of exposure outdoors were nearly identical to those exposed to the fluorescent aging test for 240 hr.

TABLE IV.—APPEARANCE OF TRANSPARENT PLASTICS AFTER LABORATORY AGING TESTS.

Sample	Type of Sunlamp[a]	After 120 hr	After 240 hr
T1	F	Crazing over entire surface, slightly tacky	Slightly yellow, solidly crazed, no longer transparent
	S-1	Slightly crazed, slightly tacky	Slightly yellow, solidly crazed, no longer transparent
T2	F	Small round spots over surface	Yellow, crazed over entire surface
	S-1	No significant change	Slightly yellow, very slight crazing on some specimens
T3	F	Small round spots over surface	Yellow, crazed over entire surface
	S-1	No significant change	Slightly yellow, very slight crazing on some specimens
T4	F	Deep yellow, crazing over entire surface	Deep yellow, solidly crazed, chalky, no longer transparent
	S-1	Yellow, crazed	Deep yellow, slightly tacky, almost solidly crazed, no longer transparent, exudation
T5	F	No significant change	Very slightly yellow
	S-1	No significant change	Very slightly yellow
T6	F	Very pale green	Pale yellowish green
	S-1	Very pale green	Pale green
T7	F	Slightly yellow	Pale yellow
	S-1	Very slightly yellow	Very pale yellow
T8	F	No change	No change
	S-1	No change	No change
T9	F	Slightly yellow	Pale yellow
	S-1	Very slightly yellow	Very pale yellow
T10	F	Slightly yellow	Pale yellow
	S-1	Very slightly yellow	Very pale yellow
T11	F	Very slightly yellow	Slightly yellow
	S-1	Very slightly yellow	Very slightly yellow
T12	F	Very slightly yellow	Slightly yellow
	S-1	Very slightly yellow	Very slightly yellow
T13	F	Pale yellow	Yellow
	S-1	Pale yellow	Yellow
T14	F	Pale yellow	Yellow
	S-1	Pale yellow	Yellow
T15	F	Pale yellow	Yellow
	S-1	Pale yellow	Yellow
T16	F	Pale yellow	Yellow
	S-1	Pale yellow	Yellow
T17	F	Pale yellow	Yellow
	S-1	Pale yellow	Yellow
T18	F	Pale yellow	Yellow
	S-1	Pale yellow	Yellow
T19	F	Pale yellow, slight crazing	Yellow, considerable crazing
	S-1	Slightly yellow, slight crazing	Pale yellow, considerable crazing

[a] F = fluorescent sunlamp, and S-1 = S-1 sunlamp.

Laminates

There was no apparent change in the appearance of the three canvas phenolic laminates, samples L1 to L3, after exposure to the two laboratory aging tests. When the specimens were wiped with a wet cloth, they became yellow. The appearance of the specimens of samples L1 to L3 was similar after 5 weeks of exposure outdoors to that of specimens exposed to both laboratory tests for 240 hr; the specimens were slightly faded after 10 weeks of exposure. The paper phenolic laminate, L4, faded considerably in both laboratory tests; the fading was more severe under the fluorescent sunlamp. Sample L4 had faded noticeably after 5 weeks of exposure outdoors and very severely after 10 weeks of exposure. Sample L5 turned yellow in both the laboratory tests with specimens exposed to the fluorescent sunlamp becoming a deeper yellow. The specimens exposed outdoors for 45 weeks became a lighter shade of yellow than those exposed to both laboratory aging tests for 240-hr.

Samples L6 and L7 faded in both laboratory tests to about the same extent after 120 hr of exposure. The fading of both samples after 240-hr exposure was slightly greater under the S-1 sunlamp. The specimens exposed outdoors for 5 weeks were faded slightly more than after the 240-hr laboratory tests. After 28 weeks of exposure outdoors, these samples were badly faded.

The decorative laminates, samples D1 and D2, were apparently unaffected by the exposure to the two laboratory tests and to exposure outdoors for 5 weeks. The specimens were slightly faded after 10 weeks of exposure outdoors.

Upholstery Materials

The results of the tests with vinyl chloride plastic upholstery materials are presented in Tables VI and VII. These results show that the effects produced by the S-1 and fluorescent test

TABLE V.—APPEARANCE OF TRANSPARENT PLASTIC MATERIALS AFTER OUTDOOR WEATHERING TESTS.[a]

Sample	After 5 weeks of Exposure	After 10 weeks of Exposure	After 21 weeks of Exposure	After 28 weeks of Exposure	After 45 weeks of Exposure
T1	No apparent change	No apparent change	Cloudy appearance	Delaminated along edges, top layer chalky and crazed	Top layer chalky, crazed, very brittle and almost completely separated
T2	No apparent change	No apparent change	No apparent change	No apparent change	No apparent change
T5	No apparent change	Specimen curled, brittle	Cloudy appearance, specimen broke into pieces	No apparent change	No apparent change
T6	No apparent change	No apparent change	No apparent change	.....	.....
T13	Very slightly yellow	Slightly yellow	Yellow	Deep yellow	Deep yellow
T14	Yellow	Yellow	Yellow	Deep yellow	Deep yellow
T15	No apparent change	Slightly yellow	Yellow	Deep yellow	Deep yellow
T16	Yellow	Yellow	Yellow	Deep yellow	Deep yellow
T17	Yellow	Yellow	Yellow	Deep yellow	Deep yellow
T19	No apparent change	No apparent change	Yellow	Yellow	Very yellow, no longer transparent

[a] Exposed outdoors in Washington, D. C., at 45 deg facing south.

TABLE VI.—DESCRIPTION OF PLASTIC UPHOLSTERY MATERIALS AFTER LABORATORY AGING TESTS.

Sample	Color	Type of Sunlamp[a]	After 120 hr	After 240 hr
U1	Red	F	Slightly shiny and tacky	Not so shiny, tacky
		S-1	Slightly shiny and tacky	Shiny and very tacky
U2	White	F	No apparent change	Grayish yellow, stiff
		S-1	No apparent change	Very slightly yellow, stiff
U3	Blue	F	No apparent change	Faded very slightly, stiff
		S-1	No apparent change	Faded very slightly, stiff
U4	Red	F	Faded, pinkish red	Very much faded, pinkish red, stiff
		S-1	No apparent change	Faded, pinkish red, stiff
U5	Wine	F	Slightly darker	Very much darker
		S-1	Slightly darker	Very much darker
U6	Green	F	No apparent change	Slightly shiny
		S-1	No apparent change	Slightly shiny
U7	Green	F	Slightly darker	Much darker
		S-1	Slightly darker	Much darker
U8	Navy blue	F	No apparent change	Darker, stiff
		S-1	Very slightly faded	Much more faded, stiff

[a] F = fluorescent sunlamp, and S-1 = S-1 sunlamp; specimens exposed at a distance of 7 in.

TABLE VII.—DESCRIPTION OF PLASTIC UPHOLSTERY MATERIALS AFTER OUTDOOR WEATHERING TESTS.

Sample	Color	After 5 weeks	After 10 weeks	After 28 weeks	After 45 weeks
U1	Red	Shiny	Shiny	Darker, chalky	Very chalky
U2	White	No apparent change	No apparent change	Slightly gray	Slightly yellow
U3	Blue	No apparent change	Very slightly faded	Slightly faded	Faded
U5	Wine	Blue spots over surface	Solid blue	Solid blue	Solid blue
U7	Green	Faded	Faded	Very faded, dull	Very faded
U8	Navy blue	Slightly darker	Almost black, dull	Dull black	Dull black

[a] Exposed outdoors in Washington, D. C., at 45 deg facing south.

procedures are very nearly the same except for sample U8 after 240 hr. In this case, the fluorescent sunlamp caused the specimens to become darker and the S-1 sunlamp caused fading. The results of the outdoor tests with these materials were similar to those obtained with the laboratory tests except for samples U5 and U8. Sample U5 became a darker wine color in both laboratory tests and turned blue outdoors. The results of the outdoor tests with sample U8 were similar but more severe than those obtained with the fluorescent sunlamps.

Reinforced Flexible Glazing

The results of the tests of the reinforced flexible plastic glazing materials samples R1 to R4, are presented in Table VIII.

The light transmission and haze values indicate that the results of the tests made with the two lamps are nearly alike. The specimens exposed to the fluorescent sunlamp appeared to be affected slightly more than those exposed to the S-1 sunlamp. The white cotton thread in sample R1 turned yellow in both tests, with a slightly deeper shade being produced by the fluorescent lamps. The green cotton thread in sample R2 faded to about the same extent in both tests. Specimens of sample R3 tended to delaminate and sample R4 turned slightly yellow in the fluorescent sunlamp tests.

The deterioration of the samples exposed outdoors was nearly identical to that observed in both laboratory tests; the agreement was probably better with the fluorescent test.

Automotive Glazing Materials

The results of the tests of the flexible vinyl chloride plastic automotive glazing materials, samples A1 to A4, are presented in Table VIII. These specimens were exposed outdoors on October 31, 1952, and examined after 30 weeks.

The colored samples faded and the colorless samples turned yellow in all three tests. The effects produced by the fluorescent sunlamps were more severe than those produced by exposure outdoors. In most cases, the exposure outdoors caused greater changes in light transmission and haze than either of the laboratory tests. The exposure to the fluorescent sunlamp caused a greater increase in haze than the S-1 sunlamp except for sample A4. The light transmission values were not appreciably different in the two laboratory tests.

Relative Effects of Fluorescent and S-1 Sunlamps

It would appear from Fig. 1, since the radiant energy values given for the fluorescent lamp are to be divided by 500, that the effects produced by the fluorescent sunlamp in the tests described in this report would be much less severe than those obtained with the S-1 sunlamp. However, the results obtained with the fluorescent sunlamp are judged to be slightly more severe than those obtained with the S-1 sunlamp. This reversal can be

TABLE VIII.—AVERAGE LIGHT TRANSMISSION AND HAZE VALUES IN PER CENT OF REINFORCED PLASTIC GLAZING AND FLEXIBLE PLASTIC AUTOMOTIVE GLAZING MATERIALS AFTER LABORATORY AGING AND OUTDOOR EXPOSURE TESTS.

Sample	Number of Specimens	Fluorescent Sunlamp				S-1 Sunlamp				Outdoors[a]			
		Initial		After 240 hr		Initial		After 240 hr		Initial		After 30 weeks	
		Light Transmission	Haze	Light Transmission	Haze	Light Transmission	Haze	Light Transmission	Haze	Light Transmission	Haze	Light Transmission	Haze
R1	6	75	13	72	17	75	13	72	20	...	...	...	...
R2	6	73	12	70	17	71	14	70	21	...	...	...	...
R3	3	82	6	80	10	81	10	80	7	...	...	...	...
R4	3	59	23	60	26	59	22	59	22	...	...	...	...
A1	3	80	1.3	82	6.8	81	1.4	83	5.6	79	3.0	70	17.0
A2	3	73	1.0	76	11.1	73	0.9	76	4.6	73	1.0	67	15.8
A3	3	85	7.3	85	18.5	85	7.5	87	13.8	85	8.4	80	14.6
A4	4	89	4.0	89	4.2	86	0.8	89	3.7	87	1.2	87[b]	2.8[b]

[a] Exposed outdoors in Washington, D. C., at 45 deg facing south.
[b] Average values for 2 specimens exposed to outdoor weathering for 28 weeks.

attributed in part to several factors as follows: (*a*) five fluorescent sunlamps are used in place of one S-1 sunlamp; (*b*) the distance between the bottoms of the fluorescent and S-1 bulbs and the plane of the specimens is 3 and 6 in., respectively; (*c*) the fluorescent test apparatus is enclosed so that the temperature is readily maintained at 60 ± 1 C whereas in the S-1 sunlamp test the temperature fluctuates generally between 55 and 60 C; (*d*) the walls of the enclosure in the tests with the fluorescent sunlamps may tend to reflect the radiant energy and thus produce a higher concentration than the measured values.

Summary

A new method of test for laboratory aging (accelerated weathering) of plastics is described. This method utilizes a fluorescent sunlamp in a modification of Method 6021 in Federal Specification L-P-406.[6] The results of the tests indicate that slightly more deterioration, but of the same type, is obtained with the fluorescent sunlamps than with the S-1 sunlamp now specified in Method 6021. The results also correlate very well with those obtained outdoors in Washington, D. C., except for the vinyl chloride plastics for which the correlation is only fair. The fluorescent sunlamp offers the following advantages over the S-1 sunlamp: (*a*) it is cheaper; (*b*) it can be used for a longer period; (*c*) it does not require the use of a special fixture; (*d*) the temperature of the test specimens can be controlled more readily because of the low heat output; (*e*) larger areas of material can be exposed; (*f*) the tested areas are more uniformly radiated and deteriorated.

The Relationship Between Water Content and the Accuracy with Which In-Place Densities of Sands May Be Measured

By Donald F. Griffin

Water content in addition to the shearing action caused by sampling sand for density must be taken into account if accurate in-place density measurements are desired. The author discusses a new method for calibrating a sand funnel apparatus used for measuring volumes of excavations for density and presents a method for determining water content rapidly for granular soils.

SEVERAL methods for measuring the in-place densities of dry cohesionless soils have been comprehensively investigated.[1] These methods involve a shearing action of the soil with the usual effect of causing loose sands to contract and tight sands to expand. The results for each method investigated showed an algebraic decrease in per cent deviation of densities measured by a test method *versus* increasing control densities. This trend for each method was concluded to be a straight-line relationship based on least squares of the measured data. Each of the least squares lines had a different equation not only for each density-testing method but also for each different sand tested.

One of the methods tested was the use of a quart jar with funnel attached for determining the volumes of sand excavated from various cavities. This device was used in the field in wet beach sand of known average density. The particular apparatus had given erratic results in the laboratory; consequently, the results obtained with it in the wet beach sand were believed to be inconclusive. The author's interest was stirred sufficiently to cause him to make further investigations in the Soil Mechanics Laboratory at the University of Southern California.

A gallon jug with sand funnel attached was used to determine the volumes of sand excavated for in-place density tests in this study. This apparatus had not been investigated in the previous exploration. What is believed to be a new and reliable method for calibrating a sand funnel is presented as a part of this paper. In addition, a rapid method for determining the water content of wet sand was explored and is presented here in brief. Finally, the effect of the water content on the accuracy with which in-place densities of wet sands may be determined was investigated for one method of testing: namely, the sand funnel-tube method. The media tested included two gradings from Ottawa Standard Sand.

Sand Funnel Calibration

In the previous investigation, the author had reason to believe that sand flowing from a funnel into a cavity would assume different densities in cavities of different shapes and volumes. For example, Ottawa 20–30 sand flowing from a quart jar sand funnel into a cylindrical cavity with dimensions of 7.62 cm in diameter by 4.14 cm long assumed a density of 1.631 g per cu cm. The same sand flowing from a very large sand funnel into a tube 30 cm in diameter by 10 cm long assumed a density of 1.582 g per cu cm and when flowing into an inverted cone 32 cm in diameter by 7.9 cm deep, the sand assumed a density of 1.562 g per cu cm. These figures show substantial variation one from the other.

Seven seamless brass tubes each with a different diameter were obtained. One end of each tube was capped with a metal disk. To the other end of each

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NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Donald F. Griffin, "Study and Development of Methods for Determining In-Place Densities of Cohesionless Soils," *Proceedings*, Am. Soc. Testing Mats., Vol. 54, p. 1270 (1954).

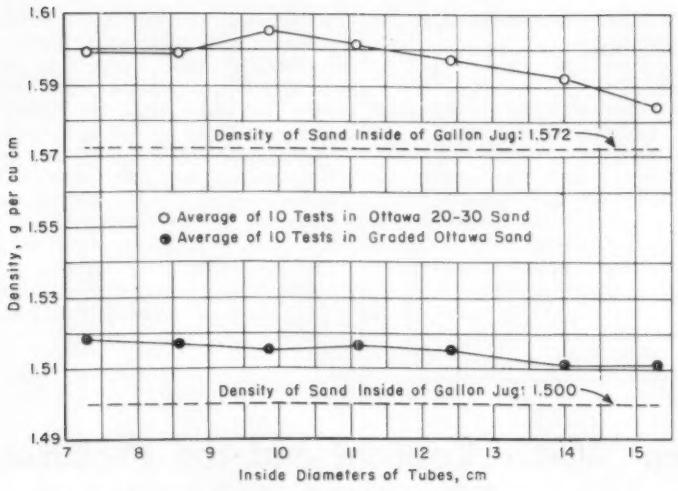

Fig. 1.—Density of Sand Inside Tubes *versus* Diameters of Tubes.

TABLE I.—DENSITY OF SAND IN TUBES AND IN JUG, G PER CU CM.

Diameter of Tube, cm	7.30	8.58	9.85	11.10	12.40	14.00	15.30	Jug
OTTAWA 20–30 SAND; RESULTS FOR 10 TESTS								
Maximum density	1.604	1.604	1.609	1.603	1.601	1.594	1.587	1.580
Average density	1.599	1.599	1.605	1.601	1.597	1.592	1.584	1.572
Minimum density	1.596	1.595	1.601	1.599	1.594	1.589	1.582	1.563
GRADED OTTAWA SAND; RESULTS FOR 10 TESTS								
Maximum density	1.522	1.522	1.518	1.519	1.518	1.515	1.514	1.507
Average density	1.518	1.517	1.515	1.516	1.515	1.511	1.511	1.500
Minimum density	1.517	1.514	1.512	1.511	1.510	1.507	1.505	1.497

tube there was attached an annular disk. A circular groove to fit the flange of the sand funnel was cut in each annular disk concentric with the longitudinal axis of the attached tube, thus assuring the centering of the funnel over the ends of the tubes.

For all calibration tests, the initial weight of the sand funnel and jug filled with sand was kept constant for a given sand. Ten tests were performed on each tube in order to arrive at an average figure for weight of sand leaving the jug. This weight included that of the sand filling the tube and the weight of the sand filling the cone above the tube. During a test the funnel was fitted to the circular groove, the funnel valve was opened, and the sand allowed to flow into the tube. A period of not less than 20 sec was allowed to elapse between the time the sand apparently stopped flowing and the time the valve was closed. The weight of the residual sand and the funnel and jug was determined and recorded. Sand was leveled off to the top of the tube with a straight edge and the weight of the sand inside the tube was determined. The volume of each tube was obtained by weighing the amount of distilled water required to fill it. Temperature of the water was taken into account and the volume of each tube in cubic centimeters was computed as a function of the density of the water in grams per cubic centimeter.

The average density of the sand inside each tube is shown plotted in Fig. 1, according to diameter of tubes, both for Ottawa 20–30 sand and for graded Ottawa sand. The variations in these densities are not large enough to be significant—less than 1 per cent of the mean density for all tubes for each sand. For both sands there appears to be some trend of decreasing densities as the diameter of the tubes is increased.

The weight of sand inside the jug when it was completely full was determined by filling the jug with sand through the attached funnel. When more than full, the valve was closed and surplus sand emptied from the cone. The volume occupied by the sand was determined on the basis of the weight of water required to fill the jug to the valve opening. The density of the sand determined by dividing the weight of the sand by the volume of the water is shown for each sand in Fig. 1, as a horizontal dashed line. In each case the density of the sand inside the jug was less than the density of the sand inside the tubes.

In Table I, there are tabulated the maximum, average, and minimum densities obtained for each sand in the various tubes as well as in the jug of the sand funnel apparatus. For the Ottawa 20–30 sand, the maximum variation in density from the mean density for any single tube is 0.31 per cent. For the graded Ottawa sand the corresponding variation is 0.40 per cent. For the jug, these variations are 0.57 per cent and 0.47 per cent, respectively.

The over-all shape of the volume receiving sand from the funnel undoubtedly is an influencing factor on the density assumed by the sand when it flows from the funnel, as evidenced in this case of the tubes *versus* the jug as well as in the case previously cited of the conic volume *versus* the cylindrical volume. If the shape of the cavity is cylindrical, variations in volume have very little effect on the density assumed by the sand.

Plots of sand density inside each tube *versus* volumes of tubes, lengths of tubes, or cross-sectional areas of tubes revealed nothing of interest. A plot of total weight of sand leaving the jug *versus* volume of tubes shows a straight-line relationship as indicated for both sands in Fig. 2. The volume of any size cylindrical cavity within the limits of the sand capacity of the jug may be computed according to the formulas shown in Fig. 2, one for each sand.

The calibration of any sand funnel in this way requires the use of only one tube of a volume nearly equal to that of the jug. If, in Fig. 2, the weight of sand for the largest volume is accepted as correct, the intermediate volumes computed by the formulas using average weights of sand leaving the jug may be compared to the known volumes as follows:

Ottawa 20–30 Sand, Computed Volume, cu cm	Known Volume, cu cm	Graded Ottawa Sand, Computed Volume, cu cm
375	375	378
757	758	755
1051	1046	1050
1391	1385	1384
1742	1746	1746
2026	2033	2033
2195	2195	2195

The maximum error of a computed volume is less than 1 per cent for any of the above volumes. It may be concluded that this method of calibrating a sand funnel is simple and probably more accurate than other methods because of its directness.

Rapid Water Content

A method for determining water contents rapidly has long been sought. It would be especially desirable to have a rapid and reliable method for field use in connection with the control of fills. The use of alcohol for displacing water and the subsequent use of ether for displacing alcohol from soil is perhaps not new. The additional use of a vacuum-air pressure differential is believed to be an original application. This method may be termed the WAEV method for the process of water displaced by alcohol which in turn is displaced by ether assisted by a vacuum-air pressure differential. The WAEV method was especially suited to this research project. It permitted quick and accurate water content determinations on the wet sand used for in-place densities. The WAEV method employs a vacuum pump attached to a Büchner funnel. A filter paper disk is placed in the funnel. The weighed wet sand is placed on the filter paper and the vacuum pump turned on. Ninety-five per cent ethyl alcohol is poured over the sand and pumped through the funnel. Next, anhydrous ether is poured over the sand and pumped through the funnel. By the WAEV method the soil sample may be dried and its water content determined within 5 min.

The accuracy of the WAEV method has been determined on a limited basis. Oven-dried samples of Ottawa sand amounting to 100.00 g each have been water soaked for several days. In each case the weight of the sand after drying by the WAEV method has been the same as its original weight to the nearest 0.01 g, the maximum error thus being 0.01 per cent. Similar experiments with (−40) soils of classification A-4 and A-6 have given results with a maximum error of 1 per cent.

Additional research should be performed on the WAEV method to determine the optimum quantities of alcohol and ether for complete drying of the soil. About 300 ml each of alcohol and ether were applied to 200-g samples of Ottawa sand for drying purposes. These quick water content checks were extremely useful in determining additional amounts of water to add to the sand to obtain desired water contents.

The water content of the sand excavated for an in-place density test was determined by oven drying the entire sample of moist sand removed. These samples usually amounted to about 3000 g. Simultaneously water contents were made by the WAEV method on smaller samples of about 200 g each. While the results for both methods compared favorably, the disagreements in values for related samples merely emphasized the difficulty of obtaining representative smaller samples.

The WAEV method could be adapted to field use by means of a portable manually operated vacuum pump. A more thorough evaluation with a wide variety of soil samples will be undertaken by the author in order to prove the method and to establish its acceptance as a standard civil engineering tool.

In-Place Density Measurements of Sand

Ottawa 20-30 Sand.—A marine plywood box was constructed with interior dimensions of 2 by 2 ft in plan by 1 ft deep. The box was filled with dry Ottawa 20–30 sand to various densities. The average density of the sand in the box was determined by dividing the weight of the sand in the box by the volume of the box as computed from averages of several measurements of its interior dimensions. The density of the sand in the box was then tested by means of the sand funnel-tube method. The tube had the following specifications: length, 18 cm; inside diameter, 12.40 cm; wall thickness, 0.24 cm; outside bevel at cutting edge, 45 deg; and a supporting annular disk at the top.

In performing a density test, the tube was pressed vertically into the sand until the lower surface of the annular disk rested on the surface of the sand. Sand was then excavated from inside the tube to within about 1 cm above the cutting edge. The sand funnel with jug full of sand was then fitted to the groove in the annular disk and the funnel valve opened. Twenty seconds after the sand had apparently stopped flowing from the jug, the valve was closed. The residual sand in the jug together with the jug and funnel were then weighed. In order to avoid mixing the two Ottawa sands, the same type of sand in the control box was also used in the sand funnel.

The initial weight of Ottawa 20–30 sand, jug, and funnel was kept constant at 7875 g. The volume of opening through the annular disk was determined to be 72 cu cm. If W_2 is the weight in grams of residual sand, jug, and funnel, these values may be substituted in the formula in Fig. 2 for Ottawa 20–30 sand and the following

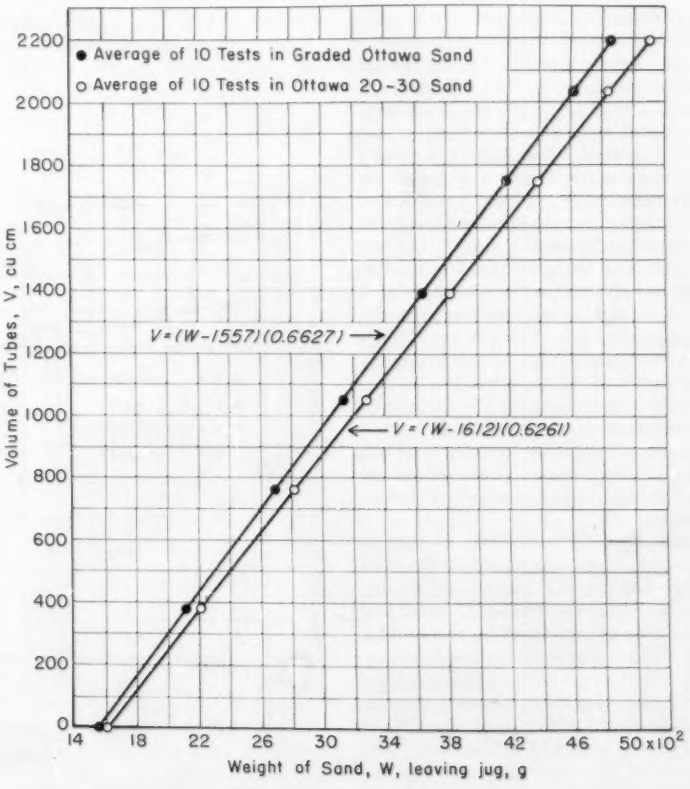

Fig. 2.—Volume of Tubes *versus* Weight of Sand Leaving Gallon Jug.

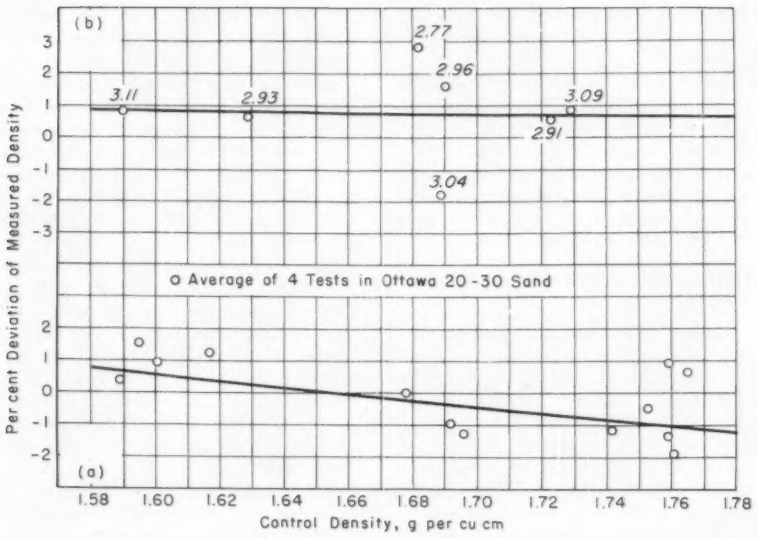

Fig. 3.—Per Cent Deviation of Measured Density *versus* Control Density. Ottawa 20–30 Sand.

(*a*) Wet sand. $w = 3$ per cent. (*b*) Dry sand.

form for computing volumes in cubic centimeters may be obtained:

$$V = 3849 - 0.6261W_2$$

The density of the sand in the tube before it was excavated was then determined simply by dividing its weight after excavation by the volume computed according to the above formula. Four such tests were performed in each boxful of sand. The measured density was then taken as the average of the four tests. The per cent deviation of this average density from the known or control density of the sand in the box was then obtained by dividing the difference between the two density values by the control density and expressing it as a percentage. The per cent deviation was termed "plus" if the density by the test method exceeded the control density and "minus" if the density by the test method was less than the control density. Results for the dry sand are shown as Fig. 3(*a*). These results are typical in the light of previous investigations.

Following the completion of tests in dry sand, water was added to the sand in the amount of 3 per cent of its dry weight. Uniform mixing of sand and water was accomplished by the use of a soil mixer. Various densities based on dry weight were obtained in the control box by tamping the wet sand in varying multiple layers with a metal disk 10 cm in diameter attached to a handle. The density of the sand was then measured by means of the sand funnel tube as before. The entire wet sample was oven dried in order to determine its water content and its dry weight. The average water content of the four tests per box was used as the average water content of the box. Typical values for water content for four tests in a given box are: 3.033, 2.980, 2.973, and 2.919.

After a series of tests at various control densities, the water content of the sand was increased to 6 per cent; however, it was observed that free water collected in the sand storage drums. The sand above the free water level was placed in the control box and tested. Tests in three such boxes of wet sand showed water contents barely above 3 per cent. Tests in the Ottawa 20–30 sand were then discontinued. Apparently, 3 per cent capillary water content is maximum for this sand.

The per cent deviation of measured densities from control densities, based on dry weight, for the wet sand is shown as Fig. 3(*b*). The effect of the water is pronounced. All densities measured were greater than control densities with the exception of one control boxful which tested less than control density. No rational explanation for this radical departure from the other values can be offered. It serves to illustrate the elusive character of sand. It did not appear feasible to take the time to dry out 4 cu ft of wet sand in order to investigate the pattern of behavior for water contents of less than 3 per cent for this sand. The numbers by the plotted points in Fig. 3(*b*) represent the water contents of the wet test samples.

Graded Ottawa Sand.—Graded Ottawa sand was next used as the testing medium. The control densities were established in a standard $\frac{1}{3}$-cu

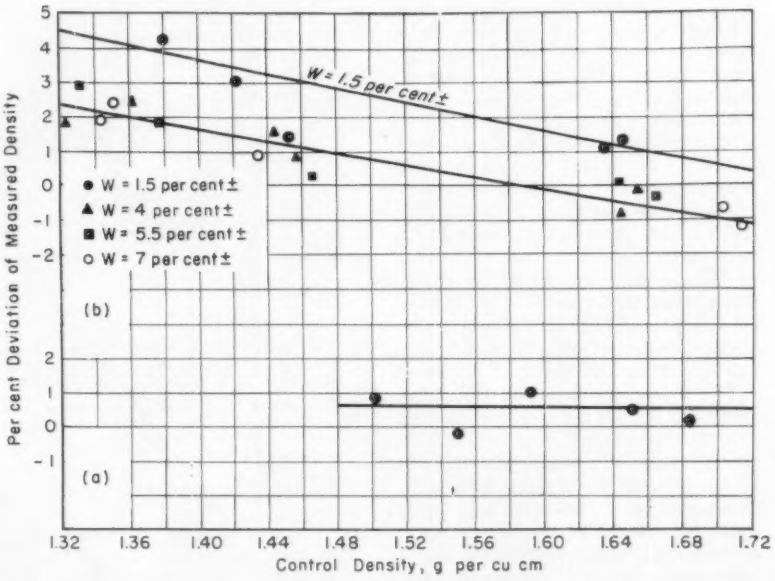
W = 1.5 per cent ±
● W = 1.5 per cent ±
▲ W = 4 per cent ±
■ W = 5.5 per cent ±
○ W = 7 per cent ±
(b)
(a)
Per cent Deviation of Measured Density
Control Density, g per cu cm

Fig. 4.—Per Cent Deviation of Measured Density *versus* Control. Graded Ottawa Sand.

(*a*) Individual tests in wet sand. (*b*) Averages of 4 tests in dry sand.

ft container. The density tests were made as before, using the sand funnel-tube apparatus. The initial weight of sand, jug, and funnel when using graded Ottawa sand was kept constant at 7850 g. The volume of opening through the annular disk was 72 cu cm as before. If W_2 is the weight of residual sand, jug, and funnel, the formula for graded Ottawa sand in Fig. 2 for computing the volume of the cavity in cubic centimeters becomes:

$$V = 4098 - 0.6627W_2$$

Results for both the dry sand and wet sand, all based on dry densities, are shown in Figs. 4(*a*) and (*b*), respectively. Apparently low water contents have the greatest effect on the accuracy with which in-place densities of sands may be measured. As the water content is increased for this particular sand, the line of deviations drops nearly parallel to the line for 1.5 per cent water content. The lines for 4 and 5.5 per cent water content coincide. The line for 7 per cent water content lies slightly below the 4 per cent line. Its proximity to the 4 and 5.5 per cent lines suggests merely a reasonable deviation from perhaps its true position of coincidence. The three lines are so close together they are represented by a single line.

Graded Ottawa sand appears to have a sharply divided line of behavior at or about 2 per cent water content. The results for two tests (not plotted) at 2.269 and 2.550 per cent water contents fall very near the single line representing the per cent of density deviations for the higher water contents. Additional control densities in the intermediate range of density for sand with 1.5 per cent water content were not obtained, as the estimated water contents for additional tests proved to be too high. Intermediate densities with higher water contents had very little influence on the placement of the least squares lines, compared to those determined on the basis of the extreme range of densities. The data for Fig. 4 are tabulated in Table II.

These experiments definitely show that wet sands react differently from dry sands when sampled for density. Moreover, the extent of the variation in reaction is dependent upon the specific water content. It is to be expected that each sand would show results similar to each other but varying in magnitude from every other type of sand.

In order to obtain the most probably correct in-place densities of sand in the field by a given test method involving shear of the soil, a comprehensive laboratory testing program would have to be made on the soil in question. By this means correction equations could be developed for various water contents and applied to field measurements.

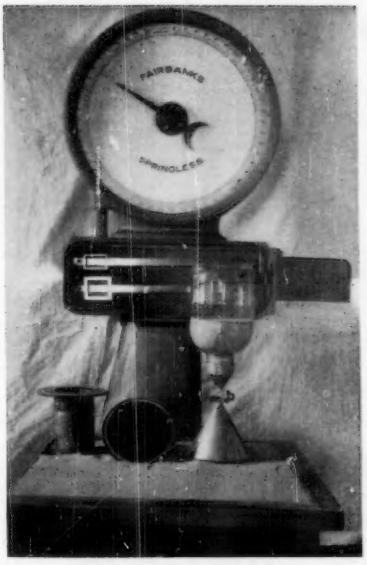

Fig. 5.—View of Test Box, Scales, Tubes with Annular Disks, and Sand Funnel-Tube In Place.

TABLE II.—TEST RESULTS FOR IN-PLACE DENSITY MEASUREMENTS OF WET GRADED OTTAWA SAND BASED ON DRY DENSITIES, G PER CU CM.

Water Content, w	Control Density	Test Density	Per Cent Error
1.479..	1.635	1.653	1.101
1.519..	1.646	1.668	1.336
1.706..	1.380	1.438	4.203
1.817..	1.422	1.465	3.024
2.269..	1.438	1.449	0.765
2.550..	1.514	1.526	0.793
3.799..	1.457	1.469	0.824
4.093..	1.654	1.652	(−) 0.121
4.118..	1.443	1.466	1.594
4.280..	1.644	1.632	(−) 0.730
4.323..	1.361	1.394	2.425
4.323..	1.323	1.347	1.814
5.354..	1.465	1.469	0.273
5.536..	1.331	1.370	2.930
5.545..	1.376	1.401	1.817
5.581...	1.451	1.472	1.447
5.656..	1.663	1.658	(−) 0.301
5.835..	1.642	1.643	0.061
6.608..	1.713	1.692	(−) 1.226
6.760..	1.452	1.472	1.377
6.864..	1.434	1.446	0.837
6.995..	1.703	1.691	(−) 0.705
7.084..	1.350	1.382	2.370
7.363..	1.342	1.376	1.863

These equations would be of the following form for sands tested in this study:

Ottawa 20–30 Sand:

Water Content, w	Correction Equation
0	$\gamma = 1.204\ \gamma_m - 0.338$
3	$\gamma = 1.000\ \gamma_m - 0.025$

Graded Ottawa Sand:

Water Content, w	Correction Equation
0	$\gamma = 1.000\ \gamma_m - 0.009$
1.5	$\gamma = 1.149\ \gamma_m - 0.267$

where:

γ = in-place dry density corrected (or control density), and
γ_m = density as measured by a test method.

The control box, scales, tubes, and sand funnel used in this research project may be observed in Fig. 5.

Conclusions

Sand Funnel.—Calibrating a sand funnel by plotting weight of sand leaving the funnel both for a zero volume of cavity and a cavity of the capacity of the sand jug appears to be a direct, simple, and accurate method worthy of consideration as a standard method. The cavities excavated for tests must have the same shape as the calibration cavity. These shapes are preferably cylindrical because the funnel opening is circular. Volumes of cavities can then be determined from a graphical plot of calibration data or computed by a simple formula expressing the straight-line relationship between weight of sand leaving the jug and volume of the cavity.

Rapid Water Content.—The WAEV method of water content determination is rapid and accurate, especially for granular soils. It could easily be adapted for field use. Additional research is needed to prove its superiority for use with clay soils.

In-Place Densities of Sand.—Moisture in sands definitely affects the accuracy with which in-place densities of sands can be measured. In general, the same trend of error holds for wet sands as for dry sands, but the magnitude of error in measurements is altered. Reliable values for in-place densities can be obtained only by the use of correction equations based on laboratory experiments under controlled conditions for each type of sand in question.

Numerical results have meaning only for the specific sand funnel and tube used in the two types of sand investigated. It is believed that qualitative results are, in general, applicable to all cohesionless soils.

The Unconfined Compression Test of Bituminous Mixtures

By H. Fred Waller, Jr.

Showing the effect on stability values of variations in the forming pressure, rate of loading, and test temperature of specific bituminous mixtures using the ASTM Unconfined Compression Test (D 1074).

A STUDY has been undertaken of certain factors which affect results secured with the ASTM Method of Test for Compressive Strength of Bituminous Mixtures (D 1074 - 52 T). The North Carolina State Highway Laboratory has selected for special study the effects of variations in the compactive pressure, rate of loading, and breaking temperature in determining the stability of specific bituminous mixtures. These tests are not extensive enough to draw absolute conclusions but they do show a pattern that would probably result by altering any one of the aforementioned items. Indications resulting from these tests might well be applied to other types of stability tests since they serve to emphasize the importance of following the outlined procedure exactly. This investigation is not intended to cover all of the possible variables but rather to show the importance of some of the most obvious.

The North Carolina Highway Department has recently revised bituminous paving specifications for high-type binder and surface mixtures to include stability requirements based on the unconfined compression test. Minimum limits have been set at 200 psi for binder-type mixes and 250 psi for surface mixtures. The revisions adopted were based on approximately two hundred paving projects designed with the compression test over a period of three years. During this time a concerted effort has been made to correlate the laboratory design data with field performance, and at this time results are most encouraging.

During the summer of 1954 a cooperative test series was conducted based on the compression test. Participating laboratories included two commercial testing organizations, a Government agency, and the North Carolina State Highway Laboratory. Several rather serious discrepancies were satisfactorily explained at a round-table discussion following completion of the tests. These discrepancies pointed out some slight differences in procedure which have since been eliminated. It became apparent that even slight variations from standard procedure would affect results. Molding pressure, molding temperature, rate of loading, and breaking temperature of test specimens all appear to be critical factors.

Our laboratory has found that 4 by 4-in. specimens compacted at 3000 psi by the double-plunger method more nearly approach field compactive conditions as practiced in the state than any of the other compactive methods investigated.

The results of the special laboratory study are shown in the form of curves in Figs. 1 to 5. Each point on the different curves represents an average of three test specimens. All specimens for each individual chart were prepared with the same job mix formula (constant-aggregate grading and bitumen content).

Figures 1, 2, and 3 are all based on the same set of test specimens. In this series the variable was compactive pressure in forming the specimens. Specimens were broken at the standard test temperature of 77 F at a rate of loading of 0.2 in. per min. Forming pressure was varied by increments of 500 psi from a low of 500 psi to a maximum of 6000 psi. All test specimens were formed using the double-end plunger method of compaction.

In Fig. 4 the variable involved was rate of loading in breaking the test specimens. Load was increased in in-

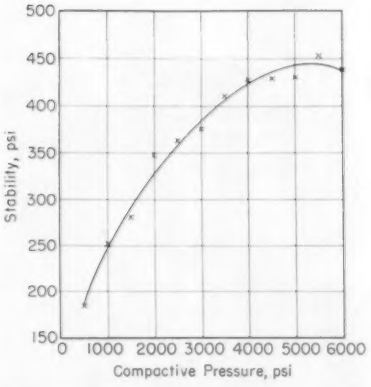

Fig. 1.—Effect of Variable Compactive Pressures on Stability.

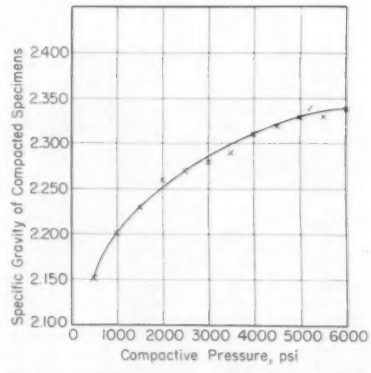

Fig. 2.—Effect of Variable Compactive Pressures on Specific Gravity of Test Specimens.

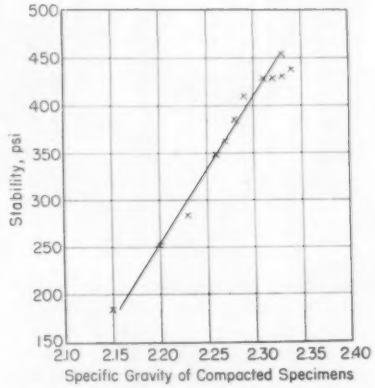

Fig. 3.—Density *versus* Stability Using Variable Compactive Pressure in Forming Test Specimens.

H. FRED WALLER, JR., Materials Engineer, Bituminous Research Dept., North Carolina State Highway Commission, Raleigh, has been active in establishing a system of bituminous design for the Highway Dept. and in 1955 received a state award for his work in this field.

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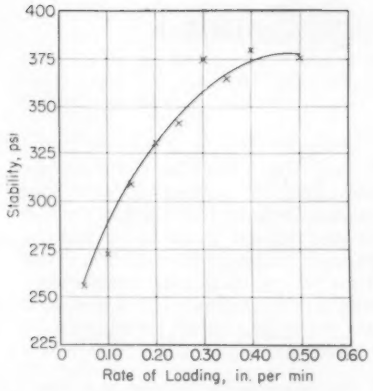

Fig. 4.—Effect of Variable Rates of Loading on Stability.

crements of 0.05 in. per min from a low of 0.05 to a high of 0.50 in. per min. Forming pressure was the standard 3000 psi and test temperature was 77 F. The average specific gravity of this group was 2.259.

Figure 5 shows the effect of variations in breaking temperature above and below the standard test temperature of 77 F. Test temperature was varied by increments of 2 F from a low of 67 F to a high of 85 F. The standard pressure of 3000 psi was used in forming the specimens, and load was applied at 0.2 in. per min in breaking the specimens. The average specific gravity of this group was 2.272. Special attention is called to Fig. 5 since close control of the test temperature appears to be the most important item of the test procedure.

It is believed that when the forming pressure reached the vicinity of 4000 psi any additional compactive effort does more harm than good. At this point the pressure begins to fracture the aggregate and cause degradation within the mixture.

The materials used for each set of mixes are as follows:

A—Coarse aggregate—crushed granite stone from Neverson Quarry. Fine aggregate—granite screenings from Woodlief Quarry. (Bitumen 85/100 penetration asphalt) (see Figs. 1, 2, and 3).

B—Crushed granite stone from Neversone Quarry—Fine aggregate from local deposit (Shaw Pit)—limestone filler from James River Hydrate Co. (Bitumen 85/100 penetration asphalt) (see Fig. 4.)

C—Crushed granite stone and screenings from Rolesville Quarry. (Bitumen 85/100 penetration asphalt) (see Fig. 5).

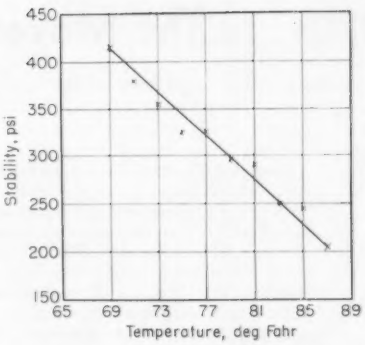

Fig. 5.—Effect of Varying Breaking Temperatures on Stability.

Compositions of each of the materials tested are shown in Table I.

Obviously, too much or too litttle forming pressure will make considerable difference in the density and stability of a mixture. Specifically, when specimens were formed at 2500 psi (Fig. 1) they produced a stability of 362 psi; a forming pressure of 3000 psi produced 375 psi stability; and a forming pressure of 3500 psi produced a stability of 410 psi. Likewise (Fig. 2), a forming pressure of 2500 psi produced a compacted specific gravity of 2.27; 3000 psi pressure produced a specific gravity of 2.28; and a pressure of 3500 psi produced a specific gravity of 2.29. The differential is even greater at some of the lower compactive pressures. Referring to Fig. 4, a rate of loading of 0.15 in. per min produced a stability of 308 psi; 0.20 in. per min produced a stability of 331 psi; and 0.25 in. per min produced a stability of 342 psi. Referring to Fig. 5, when the test temperature was raised from the standard temperature of 77 F, the stability was lowered. Likewise, when the test temperature was lowered below 77 F, the stability was raised.

Table II has been prepared to show the range in numerical value for each item of molding and testing procedure covered in the report that would have resulted in a stability value varying by no more than 5 per cent from the correct stability value. It should be noted from this table that in order to obtain a stability accuracy within 5 per cent the test temperature should not be permitted to vary from 77 F by more than 1.2 F.

These tests are not meant to be conclusive. It is suggested that other laboratories run similar checks before any attempts are made to form positive conclusions.

TABLE I.—COMPOSITION OF ASPHALTIC MIXES.

Sieve Analysis		Material	Material	Material
Passing	Retained	A	B	C
3/4-in.	1/2-in.	0.9	1.0	1.0
1/2-in.	3/8-in.	9.8	9.8	10.7
3/8-in.	No. 4	26.1	26.0	28.2
No. 4	No. 10	16.9	20.7	21.8
No. 10	No. 40	16.8	19.6	19.0
No. 40	No. 80	8.6	8.1	7.8
No. 80	No. 200	9.4	4.6	4.0
No. 200		6.0	4.7	2.0
Bitumen		5.5	5.5	5.5
		100.0	100.0	100.0

TABLE II.—COMPARISON OF COMPACTIVE PRESSURE, DENSITY, RATE OF DEFORMATION DURING TESTING, AND TEST TEMPERATURE WITH THEIR EFFECT ON TEST RESULTS.

Data from Plotted Curves of Figs. 1 and 3			
Compactive pressure, psi	2650	3000	3400
Numerical variation from correct compactive pressure, psi	−350	0	+400
Specific gravity of test specimen	2.272	2.284	2.296
Numerical variation from correct specific gravity	−0.012	0	+0.012
Stability, psi	365	384	403
Numerical variation from correct stability, psi	−19	0	+19
Percentage variation from correct stability	−5	0	+5
Data from Plotted Curve of Fig. 4			
Rate of deformation during test, in. per min	0.16	0.20	0.25
Numerical variation from correct rate of deformation, in. per min	−0.04	0	+0.05
Stability, psi	314	330	346
Numerical variation from correct stability, psi	−16	0	+16
Percentage variation from correct stability	−5	0	+5
Data from Plotted Curve of Fig. 5			
Test temperature, deg Fahr	78.2	77.0	75.8
Numerical variation from correct test temperature	+1.2	0	−1.2
Stability, psi	264	278	292
Numerical variation from correct stability, psi	−14	0	+14
Percentage variation from correct stability	−5	0	+5

The Movement of Moisture Through Solids

By J. D. Babbitt

EDITOR'S NOTE.—There is probably no subject of wider applicability in ASTM work than that of moisture. Evidence of this may be found in the 1955 Index to Standards which contains 58 entries under the heading "Moisture Test." The presence of moisture influences corrosion of metals, it is a necessary processing ingredient for ceramics, masonry, concrete, etc., and in many structures it is important to keep moisture out (buildings) or to keep it in (tanks). Passage of moisture through the walls of a building causes paint to peel and, when it condenses and freezes, impairs insulation efficiency and does damage to the structure. Moisture influences the character and quality of soils, paper, textiles, wood, electrical insulation, leather and many other materials. Sometimes we want it present, sometimes absent. It is very desirable that it be present in cotton, but it plays hob in a mass spectrograph.

In this paper, the author reviews the various physical concepts which relate to the movement of moisture through solids, analyzing moisture movement in its six possible states—vapor, liquid, solid, chemical compound, adsorbed, and dissolved. Through better understanding of the mechanism by which moisture behaves in solids, ASTM committees can devise more meaningful tests involving moisture in engineering materials.

IT HAS been obvious for some time that the movement of moisture through porous or granular solids is a complicated phenomenon that cannot be solved completely by any single approach. The complexity and variety of the experimental results strongly suggest that moisture within a solid can exist in several states and can migrate in several ways. Accordingly, any satisfactory explanation of the movement of moisture not only must consider the physical state of the water molecules within the solid but also must include all possible modes by which the molecules might move. It may be useful, therefore, to enumerate the states in which moisture may exist in solids and, on a theoretical basis, to analyze the laws governing the movement of moisture in each of these states.

Relation Between the Moisture and the Solid

If the pores are of sufficient size, the moisture may be present in the solid as a vapor, as liquid water, or as ice. In addition, it is possible that the water molecules may be bound more or less strongly to the solid structure so that to the three classical states of matter must be added three phases to cover recognized relations between water molecules and solids: the moisture may be present as a chemical compound, it may be adsorbed on the surface, or it may be dissolved within the crystal structure of the solid. We distinguish, therefore, six possible states, namely, vapor, liquid water, ice, chemical compound, adsorbed, and dissolved. In each of these states, the water molecules, under certain conditions, are capable of movement, and all six states may contribute to the migration of the moisture.

The Generalized Equation of Flow

In general, any movement of a fluid must obey an equation of transport of the form of the Stokes-Navier equation. This equation is an expression of the forces acting on a small element of volume of the fluid. In one dimension, we may use the equation in the form:

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x} + F_x + A_x \ldots\ldots (1)$$

where D/Dt denotes differentiation following the motion of the fluid, ρ is the density, p the pressure, and u the component of the velocity in the x-direction. F_x is the external force, such as gravity, acting on the element, and A_x is the force opposing the motion of the fluid.

The term on the left is the accelerative or inertial force and in a steady state of flow is zero. We may, for this study, neglect external forces so that Eq 1 reduces to:

$$\frac{\partial p}{\partial x} - A_x = 0 \ldots\ldots\ldots (2)$$

This is a simple statement of the fact that in steady flow the pressure gradient is balanced by the resistive or frictional forces. The application of Eq 2 to the movement of moisture is instructive because it shows that the flow for each of the phases given above will be characterized by the evaluation of the pressure gradient and the resistive force. The appropriate form of these two terms for the migration of moisture in its various phases is developed below.

The Migration of Moisture as a Gas

The laws governing the flow of gases through porous solids have been well established for some years, but the relation between the various flow mechanisms has not always been explicitly expressed. The great advantage of Eq 2 is that, through its use, the operative pressure is immediately evident, and the evaluation of A_x clearly distinguishes the various mechanisms of flow.

In studying the movement of moisture, it is necessary to emphasize that moisture can move as a gas only if there are pores running through the solid of such size that the water molecules can move freely within the pores without individually coming within the influence of the solid. If moisture can move through a solid as vapor, the solid must also be permeable to other gases and the relative rates of flow will depend on molecular characteristics. On the other hand, if moisture penetrates a solid that is impermeable to permanent gases, it is evident that the moisture has not moved as a vapor. Moreover, if moisture moves through a solid, as it does through rubber, forty or fifty times as rapidly as hydrogen, it is certain that some mechanism other than gaseous flow has assisted the movement of the moisture.

In applying Eq 2 to the movement of moisture as a gas, the appropriate pres-

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sure gradient is clearly the gaseous pressure. Two possibilities, however, must be distinguished: the gas pressure may be either an absolute pressure or a partial pressure.

Gas Flow Under an Absolute Pressure Gradient

When the vapor moves through the solid under the influence of an absolute pressure, a variety of flow mechanisms are possible depending on the nature of the resistive force A_x. A_x, being a summation of the forces which impede the movement of the individual molecules through the pores, is dependent on the mean gas pressure and on the size of the pores or, more specifically, on the relation between the mean free path of the gas molecules and the dimensions of the pores. Depending on this relation, we distinguish four regions. In the first the mean free path is less than the dimensions of the pores. The resistive force arises from the viscosity of the gas, and the flow obeys Poiseuille's equation. In the second region the mean free path is greater than the diameter of the pores. The resistive force arises from collisions of the molecules with the walls of the pores, and the movement of the gas is known as molecular or Knudsen flow. A third region is characterized by a mean free path greater than the length of the pores. The molecules go through the solid without colliding either with other molecules or with the walls of the pores. Here the pore itself offers no resistance to the flow of the gas, and the presence of the porous solid limits the flow only by reducing the area that is available for the movement of the molecules. This type of flow is known as effusion or molecular streaming. In the fourth region, the mean free path is of the same order of magnitude as the dimensions of the pores. Here there is a possibility of the molecules either colliding with other molecules or hitting the walls of the pores. The resistive force is intermediate between that of the first and second regions. The flow of gas under these conditions follows an equation of the form originally developed by Kozeny.

Gas Flow Under a Partial Pressure Gradient

In the interdiffusion of gases in free space, the movement of the gas takes place under the influence of a partial pressure gradient; it is this type of gas flow that is most readily recognized as diffusion. In discussing the flow of gases through solids, there has been a tendency to speak of the diffusion of gases when the gradient has been that of an absolute pressure, and the result has been that the possibility of the movement of gas under the influence of a partial pressure gradient has been comparatively ignored. As with an absolute pressure gradient, the movement of gas under a partial pressure gradient is characterized by various flow mechanisms depending on the size of the pores and the gas pressures. Again we distinguish four types of diffusion arising from four possible sources of resistance. In the first the mean free path of the gas molecules is less than the dimensions of the pores. The resistive force is built up from the resistance offered by the molecules of one gas to the movement of the molecules of the other. The mechanism is the same as in the interdiffusion of two gases in free space except that the presence of the solid restricts the volume that is available for diffusion. In the second region the mean free path is larger than the diameter of the pores. The molecules hit the walls of the pores more often than they collide with other molecules, and the resistance to the flow is built up from collisions with the wall. This is the type of diffusion that is known as transpiration or free molecular diffusion. It should be noted that, since the resistance arises from the collisions with the walls of the pores, it is not dependent on the presence of the second gas; accordingly, the movement of the gas through the solid is the same whether or not a second gas is present. Transpiration and Knudsen flow are similar except that in one the operating pressure is a partial pressure and in the other an absolute pressure. A third region is characterized by a mean free path greater than the length of the pores. The molecules go through the pores without hitting either other molecules or the solid. This type of flow is similar to molecular streaming except that the operative pressure is the partial pressure. In the fourth region the mean free path is of the same order of magnitude as the dimensions of the pores. This type of flow is intermediate between the first and second regions.

The Migration of Moisture as Liquid Water

The migration of moisture through a porous solid as liquid water is simply the flow of water under a hydraulic pressure. It has been experimentally established that this obeys Darcy's law which may be expressed in the form:

$$\frac{\partial p}{\partial x} + \frac{\mu}{k} u = 0 \quad \ldots\ldots\ldots\ldots (3)$$

where p is now the hydraulic pressure, μ the viscosity, k a factor depending on the permeability of the medium, and u the velocity of flow. Comparing Eq 3 with Eq 2, we see that, for the flow of liquid water, the resistive force A_x is equal to $(\mu/k)u$.

As in the discussion of the movement of moisture as a gas, it is essential to point out that, if moisture is to move through a solid as a liquid, the pores must be of sufficient size to permit the moisture to exist as free water. To realize the importance of this, it is only necessary to consider the semipermeable membrane of the classical osmotic experiment. In this experiment the external conditions are such that the moisture might be expected to flow according to Darcy's law. In fact, however, Darcy's law is not obeyed, and the moisture moves against the hydraulic gradient. It is obvious that a semipermeable membrane is so resistant to the movement of liquid water that the hydraulic pressure is not operative. The mechanism by which moisture moves through such a membrane has been outlined recently (**3, 4**)[1], and it suffices here to point out the limitations of Darcy's law.

The flow of liquid water through pores is complicated by the effect of capillary forces, which must be taken into account in calculating the hydraulic head. This is most easily done by substituting for the pressure p in Eq 3 a potential ϕ which comprises both gravity and capillary potential. The important point to remember is that, for the valid use of Darcy's law, the moisture must move as a liquid, and the resistive forces must be of the form given in Eq 3. It is clear from a study of osmotic effects that there are many situations in which moisture can exist in solids and yet be only indirectly influenced by the hydraulic pressure.

The Migration of Moisture as a Solid or as a Chemical Compound

Although we know from the movement of ice in glaciers that water can migrate in the solid phase when the pressure is great enough, this mode of migration is extremely slow compared to that of other phases and here we need only point out that the movement of the water arises from the thermal motions of the individual molecules. Even in the solid state, molecules may possess sufficient thermal energy to make the transition from one site on a crystal lattice to the next. Such a movement, of course, is a diffusion and there will be a net transfer of molecules from the places where the molecular jumps are more frequent to those places where they are less. A diffusion such as this is similar to self-diffusion in metals or to the diffusion of one metal in another. It is possible that water chemically bound to the solid may be subject to a similar diffusion; this must not be over-

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

looked as a possible method of moisture transfer.

The Migration of Moisture in the Adsorbed State

The most marked characteristic of the relation of moisture to solids is the adsorption of water vapor by hygroscopic materials. In adsorption, the water molecules are bound to the surface of the solid in such a way that they are in equilibrium with water vapor at a pressure lower than that which exists over liquid water at the same temperature. The adsorbed molecules are distributed throughout the body of the adsorbing solid, presumably on internal surfaces, and it is evident from elementary considerations that these adsorbed molecules are capable of movement within the solid.

Although adsorption is such a striking characteristic of porous solids and although it is in hydroscopic solids that the movement of moisture departs from the laws given above, there has been little effort to relate the movement of moisture in such materials to adsorption. This arises, without doubt, because, in the past, diffusion has been approached, almost invariably, through Fick's law. Fick's law states that the concentration gradient is the driving force for diffusion and, since concentration is independent of the physical state of the molecules, Fick's law does not distinguish adsorbed moisture from moisture in the gaseous or liquid phases. The use of Eq 2, on the other hand, places the driving force for diffusion in the pressure gradient and since, on kinetic considerations, pressure is a function not only of concentration but also of the individual movements of the molecules, this approach distinguishes between molecules that are bound and those that are free.

In applying Eq 2, it is important that the pressure used be the pressure exerted by the molecules themselves. We have already pointed out that in the flow of liquid water the operative pressure is the hydraulic pressure, in the flow of gases it is the gas pressure, and in the interdiffusion of gases the partial pressure. An adsorbed gas, if the molecules are free to move, will exert a pressure arising from the motions of the molecules. Since the gas is confined to a surface, the pressure will be a two-dimensional pressure tending to make the adsorbed material spread over the surface. This two-dimensional pressure is sometimes called the "spreading pressure" and is familiar as the spreading pressure of monomolecular layers on liquids.

In thermodynamics, pressure is given by the relation:

$$p = -\left(\frac{\partial F}{\partial V}\right)_{T,n} \quad \ldots\ldots\ldots (4)$$

where F is the free energy. Thus, pressure is a measure of the change of free energy when the volume is changed at constant temperature and composition. As already pointed out, the pressure of adsorbed molecules is two-dimensional so that the equation for the spreading pressure would be:

$$p_{sp} = -\frac{\partial F_{ad}}{\partial A} \quad \ldots\ldots\ldots (5)$$

where F_{ad} is the free energy of water molecules adsorbed on an area A. F_{ad} can be obtained from the adsorption isotherm, and in a recent publication (1)[1] we have indicated how an expression for the spreading pressure can be obtained for some of the more common isotherms. Since the equations are somewhat complicated, we shall not reproduce them here.

Having determined that, for the flow of adsorbed moisture, the spreading pressure is the appropriate pressure function to use in Eq 2, we must now decide the nature of the resistive force A_r. Since the picture of the migration of adsorbed moisture presented here is that of molecules moving from adsorption site to adsorption site over the internal surfaces of the solid, it is clear that the resistive force must be a function of the activation energy required to lift the molecules over the potential barriers between sites. The problem is similar to that which has occupied the solid state physicists in their research on diffusion in metals and ultimately, without doubt, will be solved in a similar way. For the present, however, it is possible to obtain a satisfactory representation of the flow by using a macroscopic rather than a molecular picture of the resistive force. If it is assumed that the moisture moves over the surface of the solid as a film moving with a velocity u, the resistive force will have the nature of a frictional force and will, therefore, be proportional to the velocity of flow. The most simple assumption is that this force is equal to Cu where C is a coefficient of resistance. With this assumption, the equation of flow takes the form:

$$\frac{\partial p_{sp}}{\partial x} + Cu = 0 \quad \ldots\ldots\ldots (6)$$

Equation 6 has been applied to the flow of adsorbed gases through solids in two recent papers (1,2) and appears to be at least qualitatively in agreement with experiment. Quantitative agreement is limited to moisture movement at low moisture contents, but this is hardly surprising since the adsorption isotherms from which the spreading pressures were derived were not themselves in agreement with the measurements at the higher moisture contents. At the least, this approach does explain the rapid increase of moisture movement at high moisture contents, and this is a strong indication that the fundamental assumptions are sound.

The Migration of Moisture in the Dissolved State

Although the relation between a hygroscopic solid and moisture is generally assumed to be an adsorption, there is, in fact, no reason why it might not be a solid solution. In a solid solution the water molecules would be dissolved within the crystal structure of the solid. The individual molecules, which, in adsorption, are attached to the surface by a single bond, would, in solution, be attached to the crystal lattice by multiple bonds; the binding would be three- rather than two-dimensional. Externally, however, the effect would be the same and, as for adsorption, the thermodynamic properties would be obtained from the isotherm. Recently Malherbe and Carman (5) have concluded that the adsorption of methanol on coal should more correctly be described as a solution than as a surface adsorption, and they have suggested that this observation may well hold for many other materials. In considering the migration of moisture in solids, it is important, therefore, not to overlook the possibility of a solid solution.

It has been pointed out above that the pressure gradient used for the diffusion of adsorbed moisture is derived from the experimental isotherm. If the moisture were dissolved in the crystal structure rather than adsorbed on internal surfaces, the same approach could be used to determine the pressure gradient, that is, the free energy could be obtained from the isotherm and the pressure obtained from the free energy by differentiation. The pressure in a solid solution would be thermodynamically analogous to the osmotic pressure of liquid solutions.

It is conceivable that the resistive factor for a solid solution will be different from that for the diffusion of adsorbed molecules, but so little is known at present about moisture that is dissolved in distinction from adsorbed that it is impossible to give a definite answer. It would seem possible, however, to handle the migration of dissolved moisture in a manner similar to that outlined for adsorption.

Summary

The above analysis covers all the physical states in which water can be present in solids and indicates possible

TABLE I.—MODES OF MIGRATION OF MOISTURE IN SOLIDS.

Physical State of the Moisture	Operative Pressure	Nature of Resistive Force[a]	Type of Flow
Gas	Absolute pressure	mfp < diameter of pores mfp > diameter of pores mfp > length of pores mfp ≐ diameter of pores	Viscous flow Knudsen flow Effusion Intermediate or Kozeny flow
Gas	Partial pressure	mfp < diameter of pores mfp > diameter of pores mfp > length of pores mfp ≐ diameter of pores	Interdiffusion of gases Free molecular diffusion Effusion Intermediate diffusion
Liquid	Hydraulic pressure	$\frac{\mu}{k} u$	Darcy's law
Solid Chemical compound			Solid diffusion
Adsorbed	Spreading pressure	Cu	Surface diffusion
Dissolved	Osmotic pressure	Cu (?)	Solid diffusion

[a] mfp = mean free path.

modes of migration of the moisture in these states. The analysis has been confined to isothermal conditions and no attempt has been made to study the effect of temperature on moisture migration. It is clear that a temperature gradient cannot be the immediate cause of the movement of moisture and can operate only indirectly by changing the pressure and the resistance factor of Eq 2. If the changes in the pressure and resistance factor are known, the effect of a temperature gradient on the migration of moisture can easily be determined. The conclusions of this paper are summarized in Table I.

References

(1) J. D. Babbitt, "On the Differential Equations of Diffusion," *Canadian Journal of Research*, Vol. A28, pp. 449–474 (1950).

(2) J. D. Babbitt, "On the Diffusion of Adsorbed Gases Through Solids," *Canadian Journal of Physics*, Vol. 29, pp. 437–446 (1951).

(3) J. D. Babbitt, "Osmotic Pressure, Semipermeable Membranes and the Blistering of Paint," *Canadian Journal of Technology*, Vol. 32, pp. 49–54 (1954).

(4) K. J. Laidler and K. E. Shuler, "The Kinetics of Membrane Processes. 1. The Mechanism and Kinetic Laws for Diffusion Through Membranes," *Journal of Chemical Physics*, Vol. 17, pp. 851–855 (1949).

(5) P. le R. Malherbe and P. C. Carman, "Swelling of Coals by Methanol and Its Significance," *Fuel*, Butterworths Publications Ltd., London, Vol. 31 pp. 210–219 (1952).

Discussion of Paper on Testing of Cements for Inherent Strength[1]

Mr. William R. Lorman.[2]—"There is today, among users of cement, much conflict of opinion upon some of the most vital principles governing the acceptance of this material, and the natural outcome of this difference is, that some tests are specified that result in no advantage to the user or the work in hand; others that give results that are misleading and fallacious as an indication of quality, interpreted as they are, and only serve to vex and hamper the manufacturer. In the absence of better information, it may be natural for the user of cement to entertain with suspicion the statements of the manufacturer affecting the quality of a cement in question, but it seems obvious that with standard specifications and uniform methods of testing, combined with full and up-to-date information upon the results of the several determinations made there would follow greater uniformity in the material, less opportunity for dispute, and a greater degree of confidence and mutual respect between men who are seeking the same attainments—excellence of material, design and workmanship, in all projects that mark the prosperity and progress of our country."

The preceding paragraph was written more than fifty years ago by Larned[3] and in a nutshell describes a situation prevalent today. As long ago as 1903, Hatt, in his discussion of Larned's paper, was aware of imperfections in the briquet testing apparatus insofar as they related to retrogressions in observed tensile strength with increasing age. Several years later, O'Hara[4] explained retrogression in tensile strength of neat-cement briquets. His explanation is applicable equally well today with regard to portland-cement mortar. Retrogression at early ages is due to the presence of rapidly hydrated calcium aluminates; beyond 28 days age, the slower hydrating calcium silicates begin to influence the tensile-strength properties of the briquet. "If retrogression in tensile strength again occurs at a later period, it is only an indication that complete crystallization [of the silicates] has taken place, and does not indicate a disrupting action. As crystallization takes place, the cement becomes more and more brittle, and consequently tensile stresses break it more easily." In the light of today's terminology in the field of portland-cement concrete, the reader need only substitute the term "hardening of the cement gel" for "crystallization."

Mr. Swayze's review of the evolution of the mortar briquet and his extensive quotations from the ASTM C-1 Subcommittee VII Report of April 1916, although interesting enough, do not prove conclusively that the briquet tension test is unworthy of retention in the ASTM specification for portland cement. I feel obliged, therefore, to state that I cannot agree with any premise that the briquet is impracticable, as a means of determining the tensile strength of portland-cement mortar, merely because of nonuniform tensile-stress distribution in the specimen.

Cloke and Evans[5] have stated the improvements needed in the apparatus employed for testing mortar briquets,

[1] M. A. Swayze, "The Testing of Cements for Inherent Strength," ASTM Bulletin, No. 209, October, 1955, p. 27 (TP181).

[2] Materials Engineer, Research Dept., U. S. Naval Civil Engineering Research and Evaluation Laboratory, Port Hueneme, Calif. The opinions or statements in this discussion are the private ones of the writer, and are not to be interpreted as expression of official U. S. Navy policy nor are they necessarily a reflection of the official views of the U. S. Naval Civil Engineering Research and Evaluation Laboratory.

[3] E. S. Larned, "Some Observations on the Effect of Water and Combinations of Sand Upon the Setting Properties and Tensile Strength of Portland and Natural Cements," *Proceedings*, Am. Soc. Testing Mats., Vol. 3, p. 401 (1903).

[4] J. M. O'Hara, "Retrogression in the Tensile Strength of Cement," *Transactions*, Am. Soc. Civil Engrs., Vol. 74, p. 398 (1911).

[5] P. Cloke and W. S. Evans, "Needed Improvements in Cement Briquet Testing Apparatus," ASTM Bulletin, No. 104, May, 1940, p. 31. Discussion, No. 106, October, 1940, p. 35.

and they have shown how the use of suitable rubber inserts in the jaws of the briquet-specimen holders would reduce or practically eliminate stress concentration on the bearing surfaces of the briquet.

Anderegg, Weller, and Fried, in their discussion[5] of the proposal made by Cloke and Evans, considered that the use of rubber would be advantageous and demonstrated the possibility of decreasing local stresses within a briquet when under the influence of modified grips. They also had promulgated[6] a logical procedure for correction of observed tensile-strength values of portland-cement-mortar briquets; the method involved a correction factor

$$K = 1 + \frac{d}{4r}$$

where:

d = width of briquet neck, and
r = radius of curvature of the neck.

The use of this method would assure an indication of true tensile strength of the mortar because the K multiplying-factor would correct for the lack of uniform stress distribution throughout the cross-sectional area of the presently used briquet neck.

Anderegg, Weller, and Fried recommended[6] that "If it seems desirable to use a briquet type of specimen, the grips should be applied as far out from the center of the specimen as possible." Based upon their investigation of the problem, apparently there is no doubt that (1) by narrowing the neck, (2) by increasing the radius of curvature, and (3) by gripping the specimen at points relatively far from the failure section, a truly uniform stress distribution could be obtainable with the mortar briquet.

In view of the preceding, I propose that serious consideration could be given to improvement of the briquet-gripping device and to the authorized use of the K factor developed by Anderegg, Weller, and Fried. Such revision of ASTM Method C 190,[7] and its attendant effect upon ASTM Method C 150,[8] certainly is a more worthy attempt at a meeting of the minds than complete abandonment of the tensile-strength requirement for portland cement.

[6] F. O. Anderegg, R. Weller, and B. Fried, "Tension Specimen Shape and Apparent Strength," *Proceedings*, Am. Soc. Testing Mats., Vol. 39, p. 1261 (1939).

[7] Method of Test for Tensile Strength of Hydraulic Cement Mortars, 1955 Book of ASTM Standards, Part 3, p. 188.

[8] Specifications for Portland Cement, 1955 Book of ASTM Standards, Part 3, p. 1.

[9] W. H. Glanville, "Mortar Tests as a Guide to the Strength of Concrete," *The Structural Engineer*, Vol. 12, May, 1934, p. 242.

The proponents of the movement to condemn the tensile strength requirement in Method C 150 may be inclined also to pronounce Method C 190 as unfit for further use. It may be well, therefore, to consider the following. Under transverse loading the extreme fiber stresses on the tension and compression sides of a prism of homogeneous material are equal; as portland-cement mortar is not truly homogeneous and as its tensile strength is but a small fraction of its compressive strength, it becomes obvious that the flexural strength of portland-cement mortar depends upon its tensile strength. "The best guide to the transverse strength of concrete is given by the transverse strength of wet mixes of 1:3 standard mortar," according to Glanville,[9] "although the tensile strength of these mixes is practically as good." Moreover, it is of further interest to note Glanville's statement that " . . . since, however, tensile strength tends to a limiting value at an earlier age than compressive strength, and a small change in transverse strength is then accompanied by a large change in compressive strength, it would seem advisable in estimating the properties of a cement to examine both the transverse and compressive strengths. This is particularly important with high-strength cements."

There are times in every laboratory when preparation of mortar prisms for flexural strength tests may not be feasible and when mortar briquets are better suited to the circumstances prevailing at the time. In other instances, for example in certain research projects, the tensile strength requirements of portland cement may be of particular significance as they relate to rupture modulus values obtained with transverse loading of mortar prisms.

In closing, I respectfully invite attention to the fact that not only is the tensile briquet a classic in the portland-cement literature but it has been found useful to both the portland-cement manufacturers and the consumers for three-quarters of a century.

MR. MYRON A. SWAYZE (author's closure).—In his discussion of my paper, Mr. Lorman has brought up several suggestions for improvement of briquet testing not covered by the previous discussion by W. C. Hanna.[1] These are for the use of rubber inserts for the briquet clips, use of a strength correction factor based on curvature of the neck of the briquet, increasing the present radius of curvature by lengthening the briquet, and by gripping the specimen at points relatively far from the failure section.

With the exception of the Anderegg, Weller, and Fried correction factor ($F = 1 + d/4r$), which is no remedy for the principal defect in the briquet, since it ignores the influence of modulus of elasticity on briquet strengths, all of the other suggestions have been tried prior to the time the authors cited had suggested them.

The 1940 recommendation of Cloke and Evans that rubber inserts be used in the briquet clips is antedated by a statement by Richard K. Meade in *Portland Cement* (1911 edition) that rubber cushioned clips "usually give results which are only 80 to 90 per cent of those obtained with standard clips." The present author had a similar experience with rubber inserts in the early 1920's.

The 1940 proposal of Anderegg, Weller, and Fried that the neck of the briquet be lengthened by increasing the radius of curvature and that the clips for gripping the specimen be applied at points relatively far from the failure section, was anticipated by John Grant in his studies of briquet sizes and shapes between 1865 and 1871. Illustrations of six shapes with minimum sections of 1½ by 1½ in. and four with 2 by 2-in. sections tested by Grant are shown by Redgrave and Spackman in *Calcareous Cements*, 1924 edition. Three specimens of each size had either very long radii of curvature along the minimum section or else a moderate center length of prismatic form. The lengths of these elongated briquet forms were 5, 6, and 7½ in., and the clips were evidently applied near their ends. While the authors do not state why Grant abandoned these shapes for what is substantially our present one, it is logical to assume that once the inequality of stresses were removed from the minimum section, it became resistant enough to pure tensile stress to transfer the breaking point to the area of the clips where unequal stresses were present.

Mr. Lorman brings up the use of mortar prisms for the determination of flexural strength of cements. While this method of testing had no place in my original paper, which was devoted to the *history* of strength testing, the matter is nevertheless very important. Properly made prisms with plane sides can be broken first in flexure, and then the ends used for compressive strength determinations with much less effort than we now expend in mixing and molding the two different mortars for briquets and cubes. With such a test specimen the tensile and compressive strengths as found will have a direct and real relation to each other.

ASTM Committee C-1 on Cement has already adopted Tentative Methods of Test for Compressive Strength of

Hydraulic-Cement Mortars[10] C 349–54 T and for Flexural Strength of Hydraulic-Cement Mortars[11] C 348 – 54 T to cover such testing, using a 2-in. prism. An addition to Federal Specification SS-C-158 on methods of testing cements has recently been proposed for determination of flexural strength of 40 by 40 by 160-mm prisms. Their specified rate of loading specimens at 600 lb per min indicates the use of a modified briquet machine for the flexure test.

The author is fully in sympathy with those who wish to obtain some measure of the ratio between transverse and compressive strengths developed by cements in mortars and concretes. Both are important to the user as well as to the cement manufacturer. It should therefore seem self-evident that the proper means to gain this desirable information is to develop ASTM Methods C 349 and C 348 to the point where enough data are at hand to write minimum flexural limits into our cement specifications. With such a valuable goal ahead of us, we should not waste time in trying to doctor up an outmoded and long discredited tension test.

[10] 1955 Book of ASTM Standards, Part 3, p. 136.

[11] 1955 Book of ASTM Standards, Part 3, p. 161.

Determination of "Water-Soluble Alkali" in Cements

By O. A. Ellingson, J. L. Gillam, and J. E. Kopanda

Five variations of the Standard Method of Chemical Analysis of Portland Cement (C 114) were studied in an effort to eliminate a number of the steps in this method. The preferred method as developed in this study consists of shaking 25 g of cement with 250 ml of water for 10 min, filtering on a Buchner funnel, and determining the K_2O and Na_2O concentrations with a flame photometer.

THE Standard Methods of Chemical Analysis of Portland Cement (C 114–53)[1] include a procedure for determining "water-soluble alkali" in cement. Since this method was developed much information has become known regarding the manner in which alkalies occur in cement.

Newkirk[2] has shown that, when a portland-cement clinker contains both SO_3 and K_2O, the K_2O will be combined as K_2SO_4 and $K_2O \cdot 23CaO \cdot 12SiO_2$ if the K_2O exceeds the quantity that can be combined with the available SO_3. If the SO_3 equals or exceeds the quantity required to form K_2SO_4 with all of the K_2O, none of the compound $K_2O \cdot 23$ Ca $O \cdot 12SiO_2$ will be formed.

If the clinker contains Na_2O and SO_3, the Na_2O will form Na_2SO_4 and $Na_2 \cdot O$ $8CaO \cdot 3Al_2O_3$ if the Na_2O exceeds the quantity that can combine with the available SO_3 as Na_2SO_4. If the SO_3 equals or exceeds the quantity required to form Na_2SO_4, none of the compound $Na_2O \cdot 8CaO \cdot 3Al_2O_3$ will be formed.

When K_2O, Na_2O, and SO_3 are all present, they form a solid solution of $K_2SO_4 + Na_2SO_4$ and the compounds $K_2O \cdot 23CaO \cdot 12SiO_2$ and $Na_2O \cdot 8CaO \cdot 3Al_2O_3$. If the quantities of these oxides are such that both $K_2O \cdot 23CaO \cdot 12$ SiO_2 and $Na_2O \cdot 8CaO \cdot 3Al_2O_3$ are present, the solid solution of the sulfates will have the composition $3K_2SO_4 \cdot Na_2$-SO_4; under other conditions, the solid solution will have other compositions.

When an oxide system, such as portland-cement clinker, is heated, a temperature is reached at which a part of the charge melts. This liquid generally contains small amounts of all of the oxides of the system. Portland-cement clinker differs from many systems in that the liquid formed by the melting of the alkali sulfates is not miscible with the liquid containing the other oxides. Hence, in the hot zone of the portland-cement kiln, the clinkers are made up of small amounts of two liquids and crystalline compounds, such as $3CaO \cdot SiO_2$ and $2CaO \cdot SiO_2$.

In this discussion, the one liquid will be referred to as the sulfate liquid and the other will be referred to as the nor-

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NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] 1955 Book of ASTM Standards, Part 3, p. 69.

[2] Terry F. Newkirk, "Effects of SO_3 on the Alkali Compounds of Portland Cement Clinker," *Journal of Research*, Nat. Bureau Standards, Vol. 47, p. 349 (1951).

mal clinker liquid. The latter, when supercooled to a glass, will be referred to as clinker glass. The sulfate liquid contains Na_2O, K_2O, and SO_3 and the normal liquid contains CaO, Al_2O_3, SiO_2, Fe_2O_3, MgO, and the other minor oxides as well as some K_2O and Na_2O, if the SO_3 content of the clinker is less than that required to convert all of the K_2O and Na_2O to alkali sulfates.

In the manufacture of portland cement, most of the alkalies very likely are in the liquids present in the hot zone of the rotary kilns. If the cooling from this condition is sufficiently slow, the solid solution of the alkali sulfates will crystallize from the one liquid and the alkalies in the normal clinker liquid will crystallize as $K_2O \cdot 23CaO \cdot 12SiO_2$ and $Na_2O \cdot 8CaO \cdot 3Al_2O_3$. If the cooling is extremely rapid, both liquids might be quenched to glasses. Under intermediate cooling conditions, some crystallization may occur and some glass may remain uncrystallized. Hence, depending upon the composition of the clinker and the cooling conditions, the alkalies in portland cement will exist as some or all of the following phases: (1) solid solution of $K_2SO_4+Na_2SO_4$, (2) glass of $K_2SO_4+Na_2SO_4$, (3) clinker glass containing K_2O and Na_2O, (4) $K_2O \cdot 23CaO \cdot 12SiO_2$, and (5) $Na_2O \cdot 8CaO \cdot 3Al_2O_3$.

[3] William C. Taylor, "Further Phase-Equilibrium Studies Involving the Potash Compounds of Portland Cement," *Journal of Research*, Nat. Bureau Standards, Vol. 29, p. 437 (1942).

[4] J. L. Gilliland and T. R. Bartley, "Water Solubility of Alkalies in Portland Cements," *Journal*, Am. Concrete Inst., Vol. 22, p. 153 (1950).

Taylor[3] pointed out that his work and that of earlier investigators showed that the amounts of water-extractable K_2O generally increased as the SO_3 content of the clinker increased. This work showed that the alkali sulfates dissolve almost immediately when the cement is mixed with water. The clinker glass, $K_2O \cdot 23CaO \cdot 12SiO_2$, and $Na_2O \cdot 8CaO \cdot 3Al_2O_3$ dissolve slowly and release the alkalies to the liquid phase of the cement paste during most of the period required for the cement to react with water. Gilliland and Bartley[4] demonstrated this by determining the soluble alkalies of neat pastes, stored at 100 F, at ages of 7, 28 and 90 days. They found that, generally, the Na_2O dissolved at a greater rate than did the K_2O. In some cases, all of the alkalies were not dissolved at 90 days.

The term "water-soluble alkali," in reality, has no meaning because all of the alkalies in portland cement can be leached from the cement with water. The alkalies that are determined by the present method for "water-soluble alkalies" are primarily those that exist in the cement as the solid solution of $K_2SO_4+Na_2SO_4$, either in the crystalline or glassy form, and those that are dissolved within a few minutes after the cement is mixed with water.

In view of this knowledge that the alkali sulfates in portland cement, either as glass or as solid solutions, dissolve almost immediately when the cement is mixed with water and that the alkalies present as clinker glass, $K_2O \cdot 23CaO \cdot 12SiO_2$ and $Na_2O \cdot 8CaO \cdot 3Al_2O_3$, dissolve very slowly, it appeared that the method for determining the "water-soluble alkali" could be greatly simplified. If the extraction period were reduced to a few minutes, the amount of water that would be combined with the cement would be very small. Hence, if one determined the alkali content in a sample of the liquid phase of the cement paste and calculated the results in terms of the original water content of the paste, the results should not be significantly in error.

Experimental

Six methods for extracting the alkalies were used in this study, as described below. Three groups of cements were used (Table I). Group *A* consisted of gray cements in which the total alkalies (K_2O+Na_2O) ranged from 0.24 to 1.05 per cent. Group *B* consisted of white cements in which the total alkalies varied between 0.13 and 0.33 per cent. Group *C* consisted of gray cements in which the total alkalies ranged between 0.27 and 0.98 per cent.

Method 1.—ASTM Method C 114–53,[1] water-soluble alkali method, except that a 50-g sample was used in all cases instead of varying the size of the sample between 25 and 150 g, as called for in the method.

Method 2.—Same as method 1 with a 50-g sample through the steps of obtaining the filtrate. The flame photometric method of ASTM Method C 228–49 T[5] was used in determining the

[5] Method C 228 has been incorporated into Method C 114 as sections 21 to 24.

TABLE I.—COMPOSITIONS OF CEMENTS.

Cement	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	MnO	SO_3	Loss on Ignition	K_2O	Na_2O	Total Alkalies	Total
Group A Cements												
No. 1	22.79	5.08	3.70	63.72	1.25	0.09	1.57	0.95	0.64	0.26	0.90	100.05
No. 2	20.55	6.40	2.62	63.42	2.75	0.14	1.81	1.21	0.67	0.38	1.05	99.95
No. 3	20.75	6.42	2.80	63.24	2.38	0.58	2.13	1.35	0.23	0.13	0.36	100.01
No. 4	21.71	4.66	2.73	64.00	3.50	0.07	1.57	1.24	0.39	0.22	0.61	100.09
No. 5	20.80	5.25	3.01	63.77	2.79	0.52	2.01	1.70	0.13	0.11	0.24	100.09
No. 6	23.13	4.72	2.32	64.49	2.55	0.12	1.22	0.98	0.44	0.08	0.52	100.05
No. 7	22.01	5.40	4.90	63.74	1.16	0.19	1.45	0.65	0.41	0.17	0.58	100.08
No. 8	22.01	5.36	2.48	63.93	2.53	0.06	1.66	1.32	0.53	0.12	0.65	100.00
No. 9	21.98	5.71	2.45	64.98	1.12	0.12	2.08	0.84	0.57	0.16	0.73	100.01
Group B Cements												
No. 1	23.1	5.6	0.33	63.5	3.6	0.012	1.4	2.4	0.10	0.03	0.13	100.072
No. 2	21.7	6.1	0.33	63.9	3.6	0.013	1.4	2.9	0.13	0.03	0.16	100.103
No. 3	23.7	5.1	0.37	65.9	1.1	0.008	1.6	2.1	0.19	0.02	0.21	100.088
No. 4	24.2	4.4	0.36	65.8	1.1	0.007	1.6	2.3	0.28	0.02	0.30	100.067
No. 5	26.2	4.4	0.32	65.8	0.64	0.084	1.3	1.0	0.06	0.27	0.33	100.074
No. 6	25.6	4.7	0.33	65.8	0.73	0.121	1.2	1.3	0.03	0.26	0.29	100 071
Group C Cements												
No. 1	22.78	4.83	3.76	64.09	1.29	0.10	1.38	0.80	0.71	0.23	0.94	99.97
No. 2	20.70	5.73	2.74	63.76	1.94	0.50	2.27	2.11	0.14	0.13	0.27	100.02
No. 3	21.94	5.76	2.46	63.52	2.57	0.16	1.51	1.06	0.68	0.30	0.98	99.96
No. 4	21.86	5.81	2.42	64.62	0.96	0.20	1.88	1.36	0.74	0.13	0.87	99.98
No. 5	20.47	6.57	2.84	63.24	2.84	0.66	1.92	1.09	0.37	0.09	0.46	100.09
No. 6	21.91	5.59	2.92	65.07	0.95	0.09	1.66	1.15	0.48	0.18	0.66	100.00

K_2O and Na_2O in the filtrate after adjusting the calcium chloride content of the acidified filtrate. Previous studies had shown that the concentration of CaO in filtrates from Method C 114–53 ranged between 0.14 and 0.18 g per 100 ml. Accordingly, the filtrate was acidified with 10 ml of concentrated HCl and made up to 500 ml. Then, 50 ml plus 8.5 ml of the stock calcium chloride solution of Method C 228 – 49 T were made up to 100 ml and analyzed for K_2O and Na_2O. The results of these determinations are converted to Na_2O, as determined in method 1, by the following formula:

$$\text{per cent } Na_2O = \text{per cent } K_2O \times 0.807 + \text{per cent } Na_2O$$

in which 0.807 is 1.849 (factor converting K_2O to K_2SO_4) × 0.4364 (factor converting Na_2SO_4 to Na_2O). For calculation purposes, in ASTM Method C 114–53, the K_2SO_4 is considered as Na_2SO_4.

Method 3.—A slurry of 25 g of cement and 250 ml of water was shaken continuously at room temperature for 10 min and filtered on a Buechner funnel until dry. The alkalies were then determined by the flame photometer on samples of 50 ml of filtrate acidified with 5 ml of concentrated HCl to which 8.5 ml of stock calcium chloride solution were added and the solution made up to 100 ml. The results were calculated to Na_2O, as in method 2.

Method 4.—A slurry of 75 g cement and 250 ml of water was shaken for 90 min at room temperature. The remainder of this method was identical with the procedure of handling and analyzing the filtrate in method 3.

Method 5.—Same as method 1 except that the size of the sample was varied as specified in ASTM Method C 114-53.

Method 6.—Same as method 2 except that the size of the sample was varied as specified in ASTM Method C 114-53.

Discussion of Results

The results by the first three methods for the group *A* cements are given in Table II. It may be seen from this table that the results obtained by method 2, in which the individual alkalies were determined with the flame photometer and calculated to equivalent Na_2O, agree very well with the values for Na_2O obtained by ASTM Method C 114–53, as modified in method 1. Because of this good agreement and because the operations of method 2 are much simpler and less time consuming than those of method 1, no further work was done with method 1.

In general, the results with method 3, shown in Table II, were in good agreement with those obtained in methods 1 and 2. However, method 1 is not identical with Method C 114–53 in that a 50-g sample was used with all cements instead of the variable size sample called for in Method C 114–53. Also, a 50-g sample was used with all cements in method 2. It was decided, therefore, to make an additional series of tests in which methods 1 and 2 were changed to correspond with Method C 114-53, with respect to the size of the sample, and method 3 was modified by changing the

TABLE II.—WATER-SOLUBLE ALKALIES IN GROUP A CEMENTS.

Cement	Water-Soluble Alkalies, per cent						
	Individual Alkali Contents				Equivalent Na_2O Contents		
	Method 2		Method 3		Method 1 Na_2O	Method 2 Na_2O^a	Method 3 Na_2O^a
	K_2O	Na_2O	K_2O	Na_2O			
No. 1	0.26	0.04	0.26	0.02	0.23	0.25	0.23
No. 2	0.39	0.07	0.38	0.07	0.38	0.38	0.38
No. 3	0.14	0.03	0.12	0.03	0.12	0.14	0.13
No. 4	0.11	0.03	0.09	0.03	0.10	0.12	0.10
No. 5	0.07	0.03	0.06	0.03	0.07	0.09	0.08
No. 6	0.09	0.01	0.08	0.01	0.08	0.08	0.07
No. 7	0.08	0.03	0.07	0.03	0.08	0.09	0.09
No. 8	0.14	0.02	0.15	0.01	0.14	0.13	0.13
No. 9	0.35	0.03	0.34	0.03	0.31	0.31	0.30

[a] $Na_2O = 0.807\ K_2O + Na_2O$.

TABLE III.—WATER-SOLUBLE ALKALIES IN GROUP B CEMENTS.

Cement	Water-Soluble Alkalies, per cent								
	Individual Alkali Contents						Equivalent Na_2O Contents		
	Method 3		Method 4		Method 6		Method 3 Na_2O^a	Method 4 Na_2O^a	Method 6 Na_2O^a
	K_2O	Na_2O	K_2O	Na_2O	K_2O	Na_2O			
No. 1	0.003	0.004	0.004	0.002	0.006	0.001	0.006	0.005	0.006
No. 2	0.005	0.005	0.005	0.002	0.005	0.001	0.009	0.006	0.005
No. 3	0.014	0.005	0.022	0.003	0.018	0.002	0.016	0.021	0.017
No. 4	0.016	0.005	0.026	0.003	0.025	0.002	0.018	0.024	0.022
No. 5	0.002	0.029	0.004	0.035	0.004	0.029	0.031	0.038	0.032
No. 6	0.001	0.033	0.002	0.035	0.003	0.033	0.034	0.037	0.035

[a] $Na_2O = 0.807\ K_2O + Na_2O$.

TABLE IV.—WATER-SOLUBLE ALKALIES IN GROUP C CEMENTS.

Cement	Water-Soluble Alkalies, per cent									
	Individual Alkali Contents						Equivalent Na_2O Contents			
	Method 3		Method 4		Method 6		Method 3 Na_2O^a	Method 4 Na_2O^a	Method 6 Na_2O^a	Method 5 Na_2O
	K_2O	Na_2O	K_2O	Na_2O	K_2O	Na_2O				
No. 1	0.26	0.03	0.26	0.03	0.28	0.04	0.24	0.24	0.27	0.25
No. 2	0.05	0.02	0.05	0.02	0.05	0.02	0.06	0.06	0.06	0.05
No. 3	0.20	0.04	0.22	0.04	0.22	0.05	0.20	0.22	0.23	0.20
No. 4	0.16	0.02	0.18	0.02	0.20	0.02	0.15	0.17	0.18	0.17
No. 5	0.20	0.03	0.22	0.04	0.22	0.04	0.19	0.22	0.22	0.22
No. 6	0.17	0.03	0.18	0.03	0.17	0.04	0.17	0.18	0.18	0.19

[a] $Na_2O = 0.807\ K_2O + Na_2O$.

size of the sample from 25 to 75 g and the shaking period from 10 to 90 min. This modification of method 3 was called method 4 and the modifications of methods 1 and 2 were called methods 5 and 6, respectively.

The cements of group *B* were analyzed by methods 3, 4, and 6. The results are given in Table III, from which it may be seen that there is somewhat better agreement between the results by methods 3 and 6 than by methods 4 and 6.

The cements of group *C* were analyzed by methods 3, 4, 5, and 6 and the results are given in Table IV.

Methods 5 and 6 are identical, except for the methods of determining the alkali contents of the extracts. The greatest variation between the results by these two methods is 0.03 percentage points equivalent Na_2O content. This is also the greatest variation between the results by the four methods. It appears, therefore, that any one of methods 3, 4, or 6 could be substituted for method 5 (C 114) for water-soluble alkali in cement. Method 3 is preferred because of the short shaking period.

The Properties of Gypsum and the Role of Calcium Sulfate in Portland Cement

By W. C. Hansen

The author brings together and reviews briefly facts about calcium sulfate that are pertinent to the writing of specifications for portland cement.

According to Lesley,[1] portland-cement clinkers burned with oil in the early days of the rotary kiln produced cements which were very quick-setting. He claims that it was difficult to sell these cements until they were ground with gypsum in accordance with the discovery by P. I. Giron that the setting could be controlled by grinding the clinker with gypsum. Giron was led to this by having observed workmen in France add plaster to the mixing water to retard the setting of concrete used in sidewalks.

Since it prevented what is commonly known today as "flash set,"[2] calcium sulfate became known as a retarder. However, cement technologists gradually became aware that this compound did more than prevent flash set, and Lerch[3] finally showed the true role of calcium sulfate in the setting and hardening of portland-cement pastes in a paper published in 1946. Lerch studied the influence of gypsum on the rate at which cement pastes release heat, on the strengths developed by mortars, and on the volume changes of mortar prisms during storage in water and in air. Table I gives data from Lerch showing the influence of gypsum on the heat of hydration of cement pastes.

It may be seen from Table I that increasing the SO_3 content of the cement from 0.03 to 1.0 per cent decreased the amount of heat released in the first 5 min from 4.0 to 2.3 cal per g. This demonstrates the effectiveness of SO_3 in preventing flash set. However, the data show that increasing the SO_3 content of the cement from 0.03 to 1.0 per cent increased the amount of heat released at 12 hr from 9.1 to 24.4 cal per g. Thus, it is seen that SO_3 changed from the role of retarding the rate of reaction to the role of accelerating the rate of reaction. This is further demonstrated by the strengths of mortars made from these cements which are given in Table II.

The data of Tables I and II show that changing the SO_3 content of the cement within the range of 1.5 to 2.4 per cent did not markedly change either the amount of heat released or the strength of the mortar. Lerch also found that the shrinkage of mortar bars stored in air and the expansions of mortar bars stored in water were lowest when the SO_3 content of the cement from this clinker was in the range of 1.5 to 2.4 per cent. This led to the concept that there is an optimum SO_3 content for a cement made from a given clinker from the standpoint of maximum strength at early ages and minimum volume change of products made from that

TABLE I.—HEAT OF HYDRATION, CAL PER G, FOR PERIOD INDICATED.

SO_3, per cent	5 min	30 min	4 hr	12 hr	24 hr	72 hr
0.03	4.0	5.0	5.9	9.1	28.1	51.9
1.0	2.3	3.1	7.7	24.4	32.8	44.1
1.5	2.0	2.9	7.8	27.1	37.0	49.6
1.9	1.9	2.8	7.9	28.4	39.8	53.4
2.4	2.0	2.8	8.1	28.2	38.9	53.7

TABLE II.—COMPRESSIVE STRENGTHS OF MORTARS AT AGE INDICATED, PSI.

SO_3, per cent	1 day	3 days	28 days	1 yr
0.03	590	2820	7220	9 280
1.0	1250	3180	7170	9 820
1.5	1410	3420	7060	10 020
1.9	1400	3460	7280	9 960
2.4	1480	3360	7360	10 370

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[1] Robert W. Lesley, "History of the Portland Cement Industry in the United States," International Trade Press, Inc.

[2] Many portland-cement clinkers, when ground to powders without additions of calcium sulfate, give pastes with water that liberate heat very rapidly and set into masses that cannot be readily reworked to plastic pastes. This type of setting has been classed as "flash setting."

[3] William Lerch, "The Influence of Gypsum on the Hydration and Properties of Portland Cement Pastes," *Proceedings*, Am. Soc. Testing Mats., Vol. 46, p. 1252 (1946).

cement when subjected to wetting and drying.

Soon after the use of calcium sulfate became general, cement technologists found that certain cements developed what became known by such names as false set, rubber set, X-set, and premature stiffening. Pastes that showed this type of set did not become hot and the stiffening could be destroyed by additional working of the paste. Hence, this type of set could not be classed as flash set.

Brandenburg[4] appears to have been among the first to explain this type of setting[5] in terms of the setting of dehydrated gypsum formed because of high temperatures in the finishing mills. Table III shows the reactions produced by heat on gypsum.

When gypsum is first heated, it loses water to form hemihydrate which is commonly known as plaster of Paris. Further heating converts the hemihydrate to soluble anhydrite which, in turn, if heated for relatively long periods of time at relatively high temperatures is converted to natural anhydrite. All of these compounds react with water at atmospheric temperatures and crystallize as gypsum. The hemihydrate and soluble anhydrite, when mixed with water, yield solutions that are highly supersaturated with respect to gypsum, and gypsum crystallizes from such solutions very rapidly as long, needlelike crystals. It is now generally known that this crystallization of gypsum in cement pastes is one cause of false set; in fact it seems likely that this is the major cause of false set.

The stiffening produced by the crystallization of gypsum is demonstrated in the data of Table IV. In this test, quartz sand was ground to the fineness of cement with sufficient gypsum to yield a powder with an SO_3 content of 2.0 per cent. This powder was then heated to dehydrate the gypsum. It was then tested alone and in blends with powdered quartz which contained no SO_3, using a method developed in the laboratory of the Nebraska Department of Roads and Irrigation for testing for false set. This consists of mixing a paste as in the ASTM Normal Consistency Test,[6] molding in the Vicat mold, determining the penetration of the Vicat plunger at 3, 4.5, and 8.5-min intervals after the first addition of water to the powder, remixing the paste, and redetermining the initial penetration. It may be seen from these results that all of the pastes containing dehydrated gypsum stiffened appreciably in this test. The paste made up of 25 per cent sand and 75 per cent quartz contained only 0.5 per cent SO_3. These results demonstrate that a small amount of dehydrated gypsum, in crystallizing to gypsum in such a paste, can produce a measurable stiffening of the paste.

TABLE III—EFFECT OF HEAT ON GYPSUM.

$Gypsum(CaSO_4{\cdot}2H_2O) + Heat = Hemihydrate(CaSO_4{\cdot}0.5\ H_2O) + Water\ (1.5\ H_2O)$
$Hemihydrate(CaSO_4{\cdot}0.5H_2O + Heat = Soluble\ Anhydrite(CaSO_4) + Water\ (0.5\ H_2O)$
$Soluble\ Anhydrite(CaSO_4) + Heat = Natural\ Anhydrite\ (CaSO_4)$

TABLE IV.—FALSE SET IN SILICA PASTES.

Powdered Sand,[a] per cent	Powdered Quartz, per cent	H_2O, per cent	Penetration, mm			
			3 min	4.5 min	8.5 min	Remix
100	0	30.0	11	0	0	22
75	25	27.0	8	0	0	12
50	50	26.4	9	2	0	5
25	75	26.0	12	8	2	9
0	100	24.5	12	15	18	9

[a] This contained powdered gypsum.

TABLE V.—VAPOR PRESSURE IN THE SYSTEM $CaSO_4{\cdot}2H_2O$–$CaSO_4{\cdot}0.5H_2O$–H_2O VAPOR.

Temperature, deg Fahr	Vapor Pressure, *ps*, mm	Vapor Pressure Water, *pw*, mm	*ps*/*pw* × 100
32	1.17	4.57	25
50	2.78	9.14	30
68	6.24	17.4	36
104	26.3	54.9	48
110	91.4	149.0	61
176	272.4	355.0	76
212	710.8	760.0	93

Table V gives data for the dehydration of gypsum taken from Mellor.[7]

The second column of this table gives the vapor pressure of water (*ps*) over a sample of gypsum at the temperature given. The third column gives the vapor pressure of water (*pw*) over a sample of water at the temperature given and *ps*/*pw* × 100 is the vapor pressures expressed as relative humidity.

The meaning of this table is that gypsum will lose water and form hemihydrate at the temperature given if the relative humidity of the atmosphere in which it is stored is lower than the value given in the fourth column. That is, the reaction $CaSO_4{\cdot}2H_2O = CaSO_4{\cdot}0.5H_2O + 1.5H_2O$ will take place at 32 F when gypsum is stored in an atmosphere of less than 25 per cent relative humidity or it will take place at 212 F when the relative humidity of the atmosphere is less than 93 per cent. The rate of this reaction is extremely slow at the low temperatures but is relatively fast at a temperature of 212 F.

The data of Table V show that it is necessary to know both the temperature and the relative humidity of the atmosphere in a bin of cement in order to predict whether or not the gypsum in the cement can dehydrate during storage. However, these data do not show anything with respect to the rate at which the gypsum will dehydrate and, accordingly, cannot be used to predict whether or not there will be sufficient dehydration of the cement under a given set of conditions and during a given period of storage to produce a false setting cement. It seems to be believed generally that cements stored at temperatures close to 200 F are not likely to develop false set. That is, it appears that the atmosphere actually surrounding the particles of cement throughout the pile of cement may, in most cases, be high enough in moisture content to maintain a very slow rate of dehydration of the gypsum at a temperature of 200 F. It is apparent, however, that factors, such as the temperature and humidity of the atmosphere as the cement is transported to the bin, will affect the humidity of the atmosphere throughout the pile of cement and, accordingly, affect the rate of dehydration of the gypsum. It is, therefore, not surprising that cement technologists are not able to define the operating conditions necessary to eliminate completely the production of false setting cement.

Cement technologists are often asked why they continue to use this unstable compound as the retarder in cement. This question does not recognize the fact that there are many portland-cement clinkers that do not produce flash setting cements when ground without any addition of calcium sulfate. However, those cements would not be considered satisfactory from the stand-

[4] H. R. Brandenburg, "False Set of Portland Cement," *Cement and Cement Manufacture*, Vol. 2, p. 96 (1929).

[5] See R. F. Blanks and J. L. Gilliland, "False Set in Portland Cement," *Proceedings*, Am. Concrete Inst., Vol. 47, p. 517 (1951), for a good review of the literature on false set.

[6] Method of Test for Normal Consistency of Hydraulic Cement, (C 187-55) 1955 Book of ASTM Standards, Part 3, p. 178.

[7] J. W. Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Vol. III, p. 768, Longmans & Co., New York, N. Y. (1923).

point of the rate at which they develop strength. Gypsum is used in those cements for the sole purpose of accelerating the rate at which the cement minerals react with water.

Gypsum is unique in that it is an abundant natural mineral and in that it can both retard the reactions that produce flash set in cement and accelerate the rate at which cement develops strength. No natural or artificial compound or mixtures of compounds have been found that have the properties of gypsum in these respects. Hemihydrate and soluble anhydrite have the retarding and accelerating properties of gypsum and are suitable replacements for gypsum, except that they may produce a false set. However, in many types of construction, the operations are such that the false setting properties of cements containing these forms of calcium sulfate do not interfere with production of high-quality concrete.

Conductimeters, Their Construction and Use

By C. F. Gilbo

Editor's Note.—In this paper the author describes an instrument which has achieved wide use in measuring the rate of heat flow through thermal insulating materials. The instrument, called a conductimeter, measures the temperature gradient across and mean temperature of a material of known thermal resistance from which can be calculated the thermal conductivity or k value. The conductimeter is analogous to an orifice-type fluid flow meter which measures pressure drop across a known restriction.

CONDUCTIMETERS,[1] or heat meters, are tools used to measure or meter heat flow. They have found use in several engineering fields and some of these uses are described. The present paper covers the construction, calibration, and use of such meters.

Although the construction methods and materials vary widely, the basic considerations for all the heat flow meters are the same. These meters consist of a thermal resistance layer and means of measuring both the temperature drop across this layer and the mean temperature of the meter. As heat flows through the resistance layer a temperature gradient is set up which is proportional to the rate of flow. By determining the relationship of heat flow to temperature gradient for any particular meter, a meter calibration is obtained. Correlation of this calibration with the mean temperature of the meter is necessary because the output of most meters varies with temperature.

To obtain the proper working characteristics of heat meters, the following points must be considered:

1. The thermal resistance layer should be a material that will not change (physically or chemically) throughout the temperature range of intended use. It also should be a material that is thermally uniform over its entire area and will remain stable over long periods of time. It should be hard enough so that it will not be compressed in use and should be easily handled and fabricated. If the material changes while the meter is in use, then the reproducibility will be impaired. Materials used for the resistive layer include high-density corkboard, cork composition, paper, rubber, and plastics.

2. Although other temperature measuring systems could be used, most workers have found thermocouples most adaptable and most reliable from a reproducibility standpoint. It is important to choose thermocouple materials that are easy to work, that produce a large measurable signal with a small temperature difference, and that will not change in use.

Both copper-constantan and chromel-constantan thermocouples have been found satisfactory. The advantage of chromel-constantan over copper-constantan lies in its lower over-all thermal conductivity and higher emf output. However, copper-constantan material has the advantage of having no thermoelectric potentials (thermals) at the junction of the leads since the copper leads are connected directly to the copper. When chromel-constantan is used, it is necessary to connect the copper leads to the chromel and these junctions then become thermals that have to be controlled. Of course, this control only means making sure that both junctions are at the same temperature, which necessitates keeping them very close together, a condition sometimes inconvenient and difficult to accomplish.

The thermocouple system of temperature measurement has several advantages over other systems. The fine wires or thin strips of metal that make up the thermocouple system are easily fabricated and incorporated into the final unit. The thermocouples can be connected in series to give an increased sensitivity.

The only other system that will give sensitivities equaling that of the thermopile and also be as easy to use is a system of resistance thermometers. This resistance system has been used, but not so extensively as the thermocouple system, because of the difficulty of making a differential connection. With thermocouples connected in series and so arranged that all the like junctions are on one side of the thermal resistance layer and all the other junctions are on the other side, the difference measurement is automatically obtained.

Equipment Applications

The description given below applies to a low-conductance meter of the type built at this laboratory.

The material chosen for the resistance layer is ½-in. thick, high-density

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[1] Also spelled conductometer.

corkboard cut to 8 by 8-in. size. This is the size of the guarded hot plate which will be used in the calibration. It is necessary to have two meters because the guarded hot plate must have a pair of specimens for a sample.

The metering area of the 8 by 8-in. guarded hot plate is 4 by 4 in. so all thermojunctions of the heat meters are kept inside this center area. Outside this area there is no guarantee that the heat flow is perpendicular to the surfaces of the meter, a condition necessary for an accurate calibration. As an added factor of safety, the junctions are kept within the center 3 by 3-in. area.

To determine the number of couples necessary to give the sensitivity needed, the lowest heat flow to be measured (7.5 Btu per hr through each sq ft of meter in the case in question) is estimated and this value is used to determine the temperature drop across the meter. This can be done because the thermal conductivity of the high-density corkboard is known, as are the dimensions involved. As an example:

$$\text{Temperature drop (deg Fahr)} = \frac{(\text{Btu per hr sq ft}) \times \text{thickness (in.)}}{\text{thermal conductivity } (k)}$$

$$= \frac{7.5 \times 0.5}{0.3} = 12.5 \text{ F.}$$

To measure this temperature drop with a sensitivity of 0.1 per cent, we should be able to measure changes of 0.0125 F. With the potentiometer intended for this work, the smallest graduation is 0.01 mv. Chromel-constantan thermocouples produce about 0.03 mv per deg in the temperature range being considered. Enough thermocouples will be needed to produce 0.01 mv with a temperature difference of 0.0125 F. If one thermocouple will produce 0.0125 × 0.03 or 0.0004 mv for the 0.0125 F temperature difference, then it will take 0.01/0.0004 or 25 chromel-constantan thermocouples to do the job. This means there will be 25 thermojunctions per side which could be distributed as illustrated in Fig. 1. This illustration also shows the knife-cuts into which the thermocouple wires are anchored and how they are carried around the edges of the corkboard.

From experience we have found that one of the best ways to fasten small wires to a material like corkboard is to make a shallow knife cut in the surface and then press the wire into this cut. For most conductimeters of the type being discussed, No. 30 wire is usually used. This is easy to handle and has a sufficiently low electrical resistance so that the finished meter will have a low total resistance permitting the output to be easily read on an ordinary potentiometer or galvanometer type instrument.

As pointed out in the second consideration for obtaining proper characteristics for meters, it is necessary to keep the connections of the thermopile leads with the measuring leads close together where dissimilar metals are used. This can be done as shown in Fig. 1, where the first lead placed is in a knife cut that is deeper than the rest, allowing this wire to be carried under all of the other wires without touching them. After this first wire is placed from the lead to the location of the first thermojunction, it is cut at this point. As this wire is chromel it will be soldered to the constantan at the first thermojunction location. A simple way to do this is to place a piece of asbestos paper between the wire and the corkboard and then solder the junction with about a $\frac{1}{32}$-in. overlap. A small pencil type soldering iron is useful here. Because the temperature range of intended use is low, soft solder may be used. Before this junction is placed back in the knife cut, all soldering flux (preferably rosin—never acid!) is cleaned from it. After the wire has been cleaned, it is placed in the knife cut with the junctions left very near the surface. The assembly progresses from this first junction on around the corkboard by progressively pushing this constantan wire in the knife cut. When the point directly opposite the original junction is reached, this wire is cut and chromel wire again soldered to it. This procedure is continued until all of the junctions have been made and the wire placed. Stranded copper wires are attached as the measuring leads.

It is also necessary to install a temperature measuring thermocouple on each face of the meter. This can be done by cementing fine wire thermocouples in knife cuts made between the knife cuts used for the thermopile or by cementing directly to the meter surface with an electrical insulation material under the thermocouple.

With the conductimeter wired, some kind of a finish is needed to anchor the wires, increase the abrasion resistance of the unit, and make it moisture resistant. One of the best materials for this purpose is a lacquer[2] which can be applied by brushing or spraying. Care should be taken to get complete coverage and a heavy coat accomplished by multiple applications. Best results are obtained by brushing the first coat and spraying the next ones.

Calibration

The calibration can be carried out in several ways. In this laboratory two

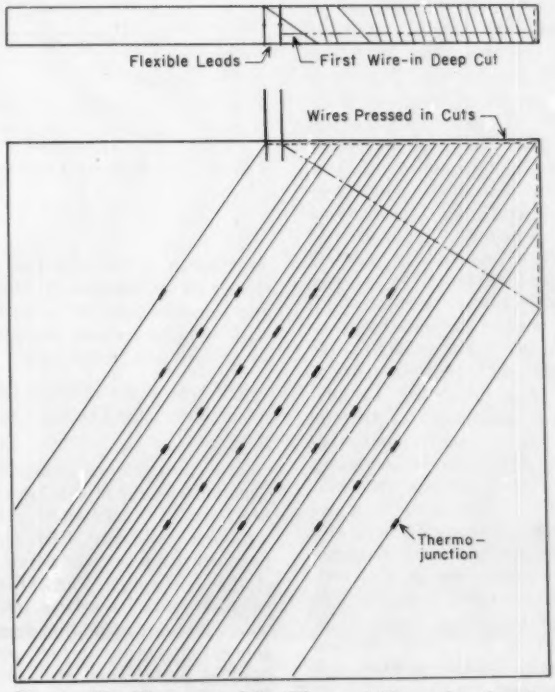

Fig. 1.—The Placement of the Wires and Thermojunctions for a Heat Meter Using 25 Thermocouples.

[2] Tygon lacquer made by U. S. Stoneware, Inc.

basic methods are used: one is a direct measurement technique where the meter is placed in a guarded hot plate thermal conductivity set as the sample. With this method, the power to the hot plate is measured and used to calculate the heat developed, as is the normal procedure when using this type of equipment. This quantity of heat is assumed to be flowing equally through the meters under test. The emf produced by each heat meter is noted. By repeating this determination at several different heat levels, data are obtained that can be converted into a useful calibration factor (Btu per hr sq ft mv). As most meters are temperature sensitive, it is necessary to establish the mean temperature of the meter at each calibration point. This part of the calibration procedure produces an average factor for the two meters. It is now necessary to place the two meters together and establish a temperature gradient through them. Since the same heat passes through both meters, it is possible to compare the two and obtain an individual calibration for both. If care has been used in selecting the materials from which the meters were made and the assembly well controlled, both meters should have essentially the same calibration.

The second method and the one used most in this laboratory is a comparative one in which the uncalibrated meter is compared against a calibrated one or against a calibrated sample. Standard samples are available which have been calibrated by the National Bureau of Standards by means of the guarded hot plate method. These samples are used to check all of the heat measuring equipment used in the author's laboratory. If the heat meter and calibrated sample are placed in series and a temperature differential is established through them, it is possible to calculate the quantity of heat and to measure the emf produced by the meter. With this information and the mean temperature of the meter, it is possible to arrive at a calibration. If the heat meter is to be used in a permanent installation for the measurement of thermal conductivity, it is usually possible to rerun the standard samples at various intervals and thus recheck this calibration. As the data from these reruns are collected, it is possible to make a statistical analysis of the accumulated data. If the equipment is well constructed and controlled, it is not difficult to reproduce thermal conductivity results that check with those obtained at the National Bureau of Standards within $\pm\frac{1}{2}$ per cent.

Figure 2 illustrates a conductimeter or heat meter of the type just described. This unit contains only nine thermojunctions per side, but because it is used with a high-precision potentiometer it gives very reliable results.

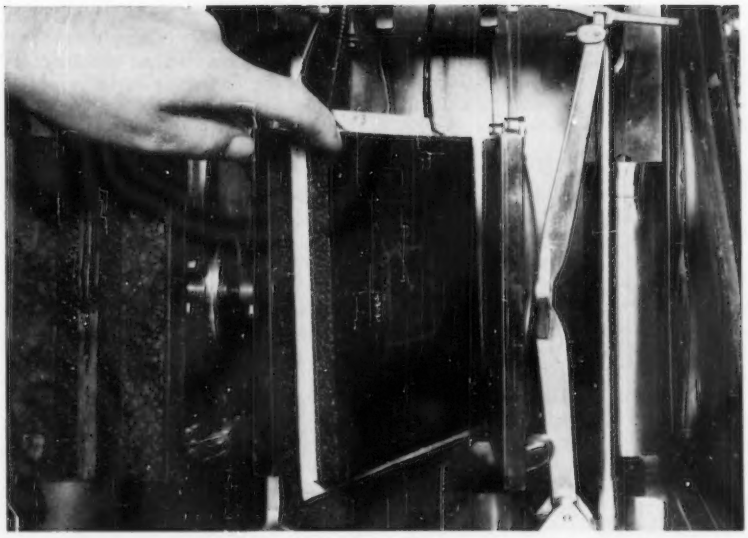

Fig. 2.—A View of a Conductimeter Thermal Conductivity Set with the Plates Held Back to Show One Surface of a Heat Meter. The thermocouples for the thermopile of the heat meter are embedded in the surface of the cork tile. The thermocouple that is visible is the one used for measuring the sample hot face surface temperature.

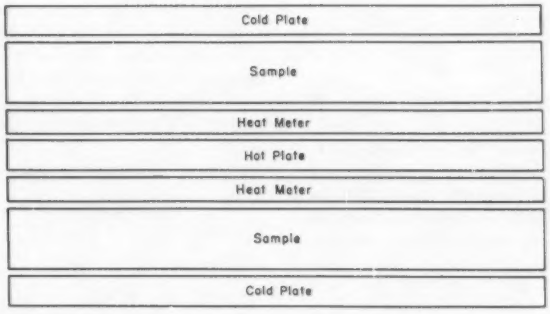

Fig. 3.—The Relative Position of the Various Units that Make up a Conductimeter Thermal Conductivity Set.

The heat meter illustrated is one from a Conductimeter Thermal Conductivity set.

The first Conductimeter Thermal Conductivity set in this laboratory was built by C. A. Peterson about 1925, although corkboard heat meters had been used earlier for panel and wall studies. Through the years, many improvements have been made in the equipment but at no time has the basic concept changed. In fact, some of the original meters are still being used. The major changes have been in the accessory equipment, such as potentiometer, wiring, electrical control, constant temperature water supply, etc.

Figure 3 is a schematic sketch of a conductimeter thermal conductivity set. Most of our units of this type make use of an 8 by 8-in. uniformly wound hot plate. This hot plate has no guard as does the conventional guarded hot plate. The conductimeters are usually located on each side of this hot plate with the samples placed between the heat meters and the cold plates. The heat passes from the hot plate out both sides, through each heat meter, on through each sample and is then absorbed by the cold plates. Because the heat that goes through either sample also has to go through a meter, it is possible with this type of equipment to measure the thermal conductivity of a single specimen.

Many advantages are realized in

equipment of the conductimeter type over the guarded hot plate apparatus. In the guarded hot plate apparatus, for example, a sample must be made up of two specimens, while in a conductimeter set only one is needed. Although the conductimeter is not an absolute measuring device, it can be calibrated to agree with a given standard with greater precision than is usually found in guarded hot plate units. Results on the conductimeter equipment illustrated in Fig. 4 can be expected to agree within $\pm\frac{1}{2}$ per cent with those of the National Bureau of Standards obtained with the guarded hot plate. This calibration can be maintained and checked by a periodic run using standard samples. At times the heat meters are used next to the cold plates with the samples against the hot plate. This is done in order to obtain higher sample mean temperatures.

Operation of Equipment

The operation of this equipment is easy and straightforward. As there are no guards to consider, one of the greatest problems encountered in most thermal conductivity measuring equipment has been eliminated. To make a thermal conductivity measurement, it is only necessary to place the sample (one specimen) between a conductimeter and the cold plate and apply sufficient pressure to provide good thermal contact. The electrical power is then turned on and the current set to the value estimated to give the proper temperature drop through the sample, usually 40 F per in. Temperature-controlled water is then run through the cold plates. The unit is allowed to reach thermal equilibrium, which in our case is overnight. When thermal equilibrium is reached, it is necessary only to measure the various emf's produced by the thermocouples and thermopiles to obtain the data necessary for a thermal conductivity measurement. When successive readings taken over a period of about an hour show no appreciable change in value, the equipment is assumed to be in equilibrium. When these equilibrium millivolt readings have been noted, they are averaged, converted to temperature and Btu per hr sq ft deg Fahr, and then used with the sample thickness to calculate the thermal conductivity and mean temperature. In routine work the cold plate temperature is changed by switching from one water bath to another water bath and allowing the equipment to reach equilibrium condition at a new mean temperature. The measurements are repeated at the second mean temperature and the results obtained from both points are used to calculate the

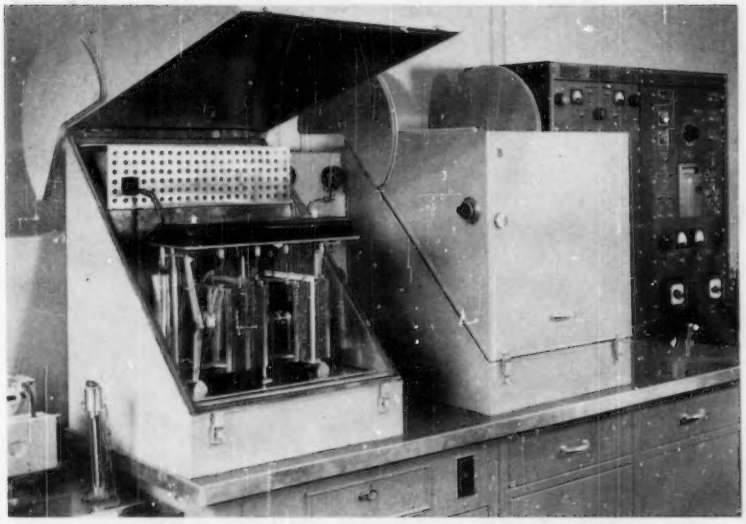

Fig. 4.—A General View of the Conductimeter Thermal Conductivity Set and Associated Equipment. The constant temperature water supplies are on the left and the control and measuring panel is on the right. Box *B* contains the guarded hot plate sets.

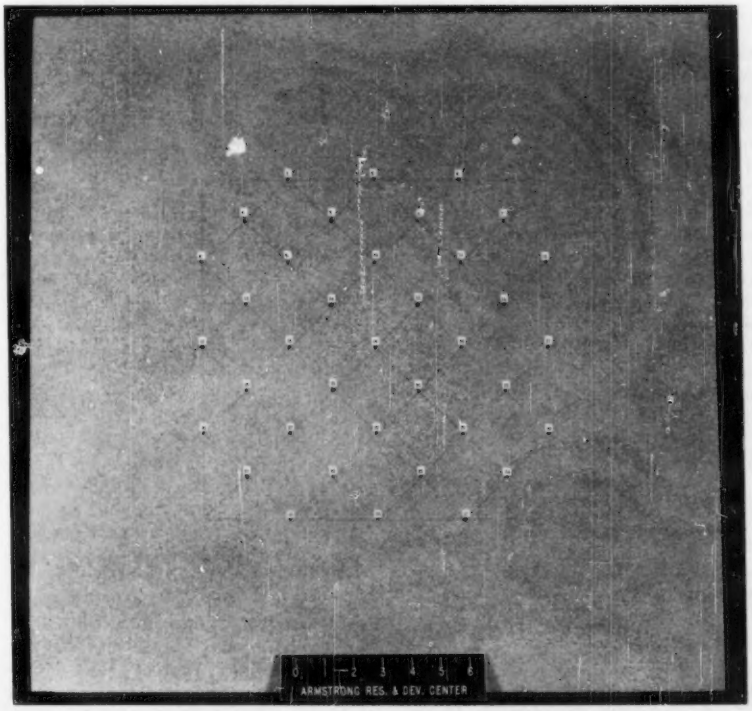

Fig. 5.—A 24 by 24-in. Heat Meter Laid Out for 37 Thermocouples. The base material is $\frac{1}{4}$-in. cork composition.

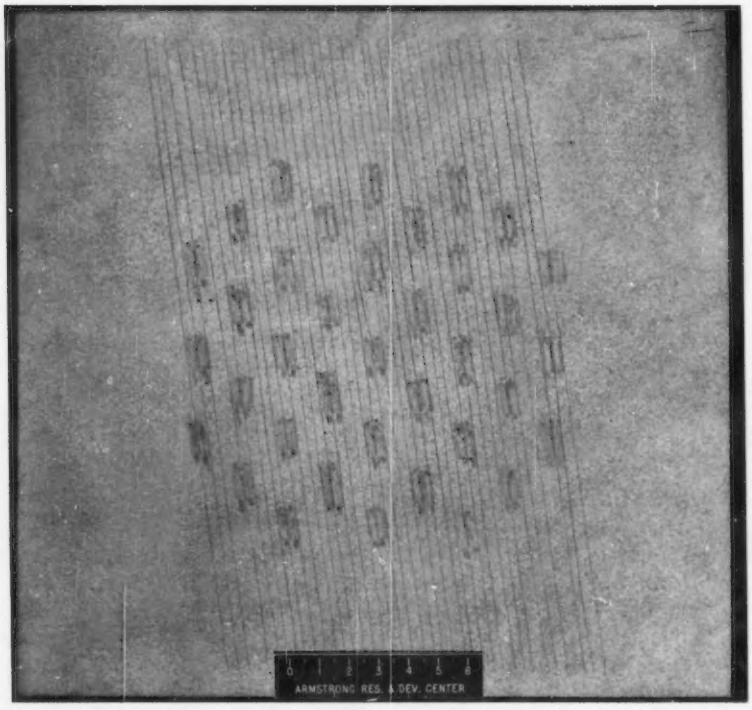

Fig. 6.—A 24 by 24-in. Heat Meter That Has Been Press Finished with a Skin of Clear Sheet Adhesive. The thermojunctions are clearly visible as are the small pieces of adhesive that were used to hold the thermojunctions in place.

slope (k per deg Fahr variation of mean) which is used to interpolate the k_{70}, k_{75}, and k_{90}. Figure 4 is an illustration of one of the conductimeter sets. This box, which occupies an area of about 4.5 sq ft of bench space, contains four conductimeter units. The accessories for this equipment consist of two constant temperature water supplies, two rheostats, two ammeters, a constant voltage supply, and potentiometer equipment. With this equipment it is possible to obtain four k values a day at an expenditure of a total time of ¾ man-hour. To aid in obtaining reliable results conveniently, the box in which the equipment is contained is provided with both dew point and dry bulb temperature control. This control aids in keeping the sample dry, permits the elimination of edge insulation around the hot plate and sample, and shortens the time necessary to reach equilibrium.

Larger conductimeter sets are also used. We have constructed 24 by 24-in. heat meters for the measurement of thick samples at mean temperatures in the range of minus 20 to plus 200 F. The construction of these meters is similar to that of the smaller ones. The primary difference is in size and the material used for the thermal resistance layer. The resistance layer is ⅝-in. cork composition. The thermopile is made with No. 30 copper-constantan wire which is cemented to the surface without the use of knife cuts or other grooves. A thermal setting sheet adhesive is used both to bond the wire and to form a hard tough face on the meters. The procedure consists of winding the series-connected thermocouples, which form the thermopile, around the cork composition so that the thermojunctions fall at the proper location. As the wire is placed, it is held down by small pieces of the sheet adhesive set with a clean soldering iron. After all of the wire is in place, the faces of the meters are covered with several thicknesses of adhesive. This adhesive is tacked in place with the soldering iron. The assembled units are then placed in a rubber press where the adhesive is pressed and cured. The thermopile wires are partially embedded in the cork composition and adhesive so that the final surfaces of the meters are smooth. Figures 5 and 6 illustrate one of these 24 by 24-in. meters at various stages of construction. This meter is used in an installation that makes use of a constant temperature room for the cold face and a 24 by 24-in. hot plate for the warm face.

The meters so far described are used where the addition of a fairly large thermal resistance does not affect the measurement. They are usually used in apparatus similar to the conductimeter thermal conductivity set described in this paper or as described by Hechler and Queer[3] or by Verschoor and Wilbur.[4]

Equipment for Other Applications

In applications where the heat flow is to be measured through building walls, boiler surfaces, and similar locations, it is impractical to use meters having low conductance. For applications of this nature, meters should have as high a conductance as possible so that their application on the surface to be measured causes a minimum disturbance of the normal thermal pattern. The exposed meter surface should be similar to the exposed surface to which it is applied for the same reason. In many applications where a finish is being put on a wall, it is possible to apply the same finish over the heat meter so that both the wall and the meter have the same surface characteristics. The higher the conductance of the wall in question the more critical becomes the heat meter application.

Several meters that are useful for determining heat flow from a surface have been described in the literature. The meter developed at the Research Laboratory of ASHVE and described in a paper by Huebacher, Schutrum, and Parmalee[5] has proved very useful for surface studies. With some modifications this type of meter has found favor in the author's laboratory. A few modifications are described by Brown and Bish[6] but many others have been made. This type of meter has been built in various sizes (24 by 24 in., 7½ by 7½ in., 4 by 18 in.) and in special shapes.

Figure 7 shows the thermopile and thermal resistance layer of two of the 4 by 18-in. meters. These meters are assembled similarly to the one described by Brown and Bish[6] except that the thermocouple ribbon is ½ in. wide instead of 1 in. and the previously used alu-

[3] F. G. Hechler and E. R. Queer, "Heat-Flow Meters and Thermal Conductivity Measurements," The Pennsylvania State College Bulletin No. 37, Vol. XXIV, August, 1930.

[4] J. D. Verschoor and Ada Wilbur, "A Rapid Heat Meter Thermal Conductivity Apparatus," *Journal*, Am. Soc. Heating and Ventilating Engrs., Section on Heating, Piping, and Air Conditioning, July, 1954, pp. 125–130.

[5] R. G. Huebacher, L. F. Schutrum, and G. V. Parmalee, "A Low-Inertia, Low Resistance Heat Flow Meter," *Heating, Piping, and Air Conditioning*, May, 1952, p. 111.

[6] H. C. Brown, Jr., and L. E. Bish, "Effect of Convections and Moisture Deposition on Heat Transmission Through Cold Storage Test Walls," *Refrigerating Engineering*, January, 1954, p. 62.

minum faces are omitted. A resin impregnated paper is used as the facing material because this more nearly matches the surface to which the meters are to be applied than does aluminum. The assembly method was changed slightly, a press pad being used on one side of the meter when it was finally assembled and cured. This produced a meter which is flat on the side to be cemented to the surface under test. Figure 8 shows a finished meter.

In addition to meters for flat surfaces, we have also constructed meters for use on pipe. Figure 9 shows one of these special heat meters built as an integral part of a test pipe. The thermopile for this unit is constructed of the copper-constantan ribbon. This unit is calibrated by the use of a heater built on the pipe, under the meter. By measuring the power dissipated by the heater and the emf produced by the heat meter, a calibration can be obtained.

Several other heat meter designs are mentioned in the literature including one used by ASHVE before the development of the one presently used utilizing the thermocouple ribbon. This previous meter was constructed of $\frac{1}{16}$ to $\frac{1}{8}$ in. thick thermosetting laminate 2 ft square. The effective metering area was $15\frac{1}{4}$ by $15\frac{1}{4}$ in. with the remaining material acting as a guard. As many as 200 thermocouples were used to measure the temperature drop through this unit. Zobel[7] describes this unit, its use, and calibration. Cammerer[8] describes a meter that is made of rubber with the thermocouples vulcanized just under the surface. This meter is 60 cm long, 6 cm wide, and 3 mm thick. Cammerer discussed some of the problems encountered in the use of heat meters on conductive surfaces (foil). When a heat meter is placed on a highly conductive surface, it causes a distortion of the heat flow so that it no longer flows perpendicularly to the surface. This distortion of heat flow can cause errors as great as −20 per cent to +40 per cent when using a meter of this type. The lower the thermal resistance through the meter the less will be this distortion.

Gier and Dunkle, have developed a thin heat meter which has been used for many purposes and which has been made in various sizes[9–14]. These meters consist of thermopile elements encased in a thin plastic slab. The thermopile ele-

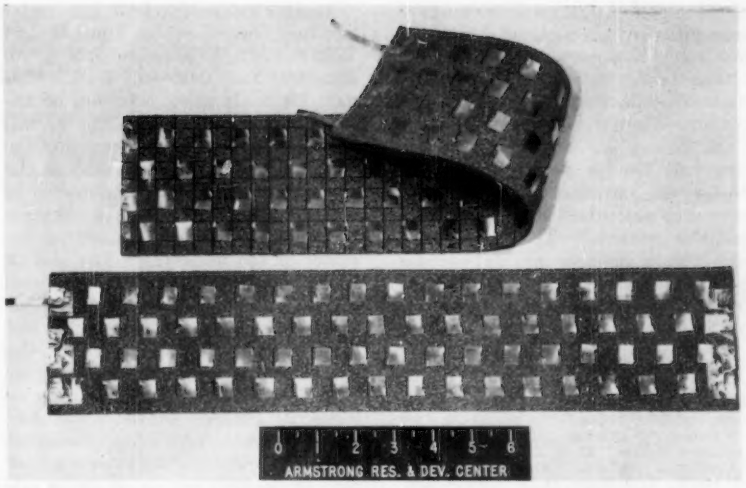

Fig. 7.—Two Thermopile and Thermal Resistance Layers Ready for Assembly into 4 by 18-in. Heat Meters. The thermal resistance layer is $\frac{1}{8}$-in. thick cork composition and the thermopile is $\frac{1}{2}$-in. wide copper-constantan ribbon cut to form the thermojunctions.

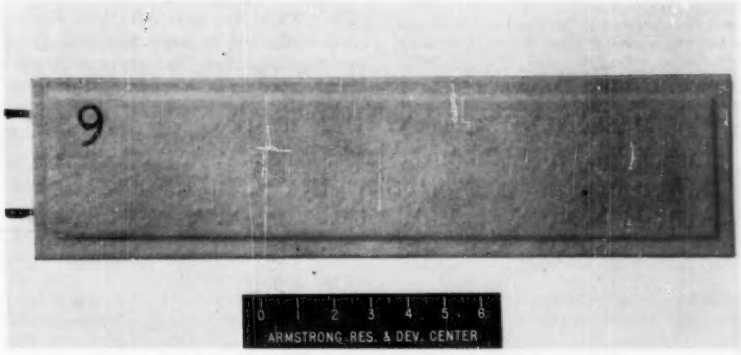

Fig. 8.—A Finished 4 by 18-in. Heat Meter with the Flat Side Down.

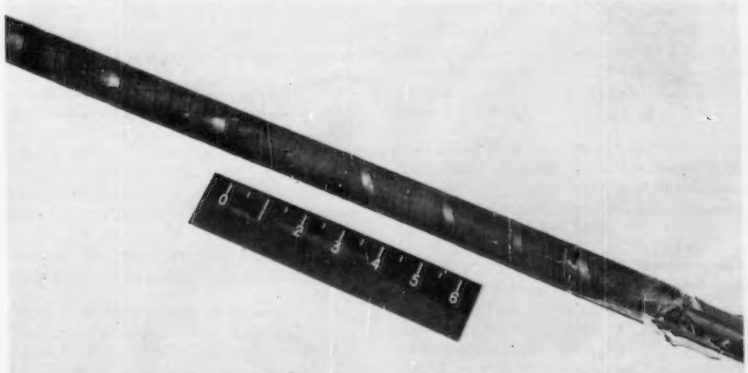

Fig. 9.—View Showing One End of a Heat Meter Built over a Pipe. The meter section uses $\frac{1}{8}$-in. cork composition as the thermal resistance layer with $\frac{1}{2}$-in. wide copper-constantan ribbon as the thermopile.

[7] Carl G. F. Zobel, "A Calibrated Thermal Resistance Plate for Measuring Heat Flow," *Review of Scientific Instruments*, Vol. 14, pp. 409–422 (1927).

[8] I. S. Cammerer, "Die Messung der Wärmeleitzahl von Isolierungen mit Blechmänteln," *Die Wärme*, November, 1937, pp. 765–767.

ments consist of thermocouples made of constantan and silver-plated constantan wire wound on a plastic form. This form acts as the thermal resistance layer. In the finished unit the thermopile elements are molded into the plastic so that there is no chance for movement. These Gier and Dunkle meters have been used as the transducers in various devices such as contact heat meters[9] and radiation meters.[10] These references also contain valuable information concerning the errors and corrections involved in various heat meter calibrations and applications.

[9] "New Meter Has Many Applications in Refrigeration Industry," *Ice and Refrigeration*, Vol. 66, October, 1948, pp. 23–24.

[10] Robert V. Dunkle, "Heat Meters and Radiation Meters," M. S. Thesis, University of California, Berkeley, Calif. (1948).

[11] L. M. K. Boelter, H. F. Coppendick, and J. T. Gier, "Experimental Inquiry into Steady State Unidirectional Heat Meter Corrections," An Investigation of Aircraft Heaters, XVII, Nat. Advisory Comm. Aeronautics (1943).

[12] L. M. K. Boelter, H. F. Coppendick, and J. T. Gier, "The Heat Meter in the Transient State for Unidirectional Heat Transfer," An Investigation of Aircraft Heaters, XXIV, Nat. Advisory Comm. Aeronautics (1944).

[13] J. T. Gier and R. V. Dunkle, "A Meter for the Evaluation of Heat Flow," *Operating Data Book*, Nat. Assn. Practical Refrigerating Engrs., 8th Edition, p. 3 (1948).

[14] J. T. Gier and R. V. Dunkle, "Using the Heat Flow Meter to Study Heat Transfer," *Refrigerating Engineering*, Vol. 62, October, 1954, pp. 63–69.

[15] H. S. Hatfield and F. J. Wilkers, "A New Heat-Flow Meter," *Journal of Scientific Instruments*, Vol. 27, January, 1950, p. 1.

Another interesting heat flow meter has been described by Hatfield and Wilkers[15] which is about 0.5 in. in diameter and 0.05 in. thick. This meter is made using tellurium or tellurium-silver alloy as both the thermal resistance layer and one element of the thermocouple. Copper is used as the second element of the thermocouple. The meters are assembled by taking a tellurium disk 0.5 in. in diameter as the center of the unit. To either side of this disk are welded pieces of 160-mesh copper gauze 0.5 in. in diameter. This welding operation is done by special machine which not only presses the gauze into the tellurium but also controls the unit's thickness. Fine copper wires are fastened to the gauze surfaces as leads. These units are claimed to have an output of 2.0 mv for a heat flow of 1 Btu per sq ft hr which is low compared with the meters previously described. But their size would make them very useful and several could be connected in series to give higher outputs when small heat flows are to be measured. These units are usually applied with an adhesive. They could be used over odd shapes and connected in series to measure the average heat flow through pipe fittings, machinery, etc. Meters of this type are now being marketed in England and are called Hatfield JLC heat-flow meter disks.

Conclusion

The material presented here should be sufficient to illustrate the basic conductimeter principles and to aid the research worker in choosing the right heat meter for his job. It should be remembered that the higher the thermal resistance used in constructing a meter the higher will be its output but the greater will be the disturbance of heat flow when the meter is applied to a surface. If the meter is to be used in a conductimeter thermal conductivity apparatus, it can be of any reasonable thermal thickness. When using heat meters on walls or panels, it should be remembered that the insulating value of the meter should be low compared to the value for the wall. The meters give best results when they are built into the wall rather than being exposed on the surface. If they are on the test surface, they should present a finish that is the same as the test area. When metering the heat from metal or highly conductive surfaces, extreme care should be used in the application of the meter to minimize the distortion of the normal isotherms. It is also important not to have air flow between the test and meter surfaces since this will remove or add heat that would not be metered.

Conductimeters are versatile tools that have proved their usefulness in many applications, but the user should always be cautious because of the ease with which errors can occur.

PERSONALS...

News items concerning the activities of our members will be welcomed for inclusion in this column

NOTE—These "Personals" are arranged in order of alphabetical sequence of the names. Frequently two or more members may be referred to in the same note, in which case the first one named is used as a key letter. It is believed that this arrangement will facilitate reference to the news about members.

Kurt Albrecht, formerly with Calgon, Inc., Pittsburgh, Pa., is now with Diamond Alkali Co., Silicate, Detergent, Calcium Div., Research Center, Painesville, Ohio.

Bruce B. Allen has been named technical director of Celanese Textile Div., Celanese Corp., Charlotte, N. C.

A. Griffin Ashcroft, for many years vice-president and director of research and development, Alexander Smith, Inc., Yonkers, N. Y., recently announced severance of connection with this firm which has consolidated with the Mohawk Carpet Co. During his 23 years of administration and direction of research and development, he had been responsible, through the efforts of his staff at Alexander Smith, for the development of a number of products, processes, and inventions in the textile industry. Active in many organizations concerned with the industry, and also in research associations, Mr. Ashcroft was a Director of ASTM (1946–49), served for several years on the Administrative Committee on Ultimate Consumer Goods, and has been very active since 1933 in the work of Committee D-13 on Textile Materials. He also served on Committee D-12 on Soaps and Other Detergents, and represented ASTM for many years on the Inter-Society Color Council. Recognition by associates of his skill in his field is evidenced by his service as president of Textile Research Institute and receipt of the 1954 Harold DeWitt Smith Award of ASTM Committee D-13 for outstanding achievement in textile fiber utilization. Mr. Ashcroft's residence is 37 Garden Ave., Bronxville, N. Y.

George D. Beal, director of research, Mellon Institute, received the 1955 Pittsburgh Award of the American Chemical Society. This is presented annually by the Pittsburgh Section of ACS for outstanding contributions to the advancement of chemistry in the Pittsburgh area. Dr. Beal has been on the executive staff of Mellon Institute for the past 30 years.

Maurice H. Bigelow, formerly director, Glendale Plaskon Laboratory, has been appointed to the newly created position of director of research at Barrett Division of Allied Chemical and Dye Corp., Toledo, Ohio. In this capacity he will be in charge of the Division's three laboratories and will be more closely associated with ASTM activities in his field.

D. C. Brand is now coordinator of standards, Engineering Dept., Research and Engineering Div., Monsanto Chemical Co., St. Louis, Mo.

E. E. Brown, formerly chief chemist, Vanadium Corp. of America, Cambridge, Ohio, has accepted a position as chief chemist with Globe Metallurgical Corp., Beverly, Ohio.

Carl Bussow of A. W. Dow, Inc., New York City, has been elected president of the Association of Consulting Chemists and Chemical Engineers. The new vice-president is **Foster D. Snell;** secretary, **Earl D. Steward** of Schwarz Laboratories; and treasurer, **W. C. Bowden,** Ledoux & Co.

Roland P. Davis is now dean emeritus, West Virginia University College of Engineering, Morgantown. Affiliated with ASTM since 1908, he expects to continue his membership. He now serves as a consulting bridge engineer for the West Virginia Road Commission, which has offices in Mechanical Hall at the West Virginia University.

Gerard R. DeNapoli, technical director and plant manager of Masury-Young Co., Boston, Mass., has been elected to the board of directors of his company. Mr. DeNapoli is chairman of Subcommittee III on Chemical and Physical Testing of ASTM Committee D-21 on Wax Polishes and Related Material.

Paul H. Dike recently retired as assistant director of research, Leeds & Northrup Co., Philadelphia, Pa. For many years Mr. Dike represented his company on a number of the technical committees of the Society, heading several subgroups. He also was a member of the Philadelphia District Council.

Ralph L. Dodge has retired as manager, Planning Div., Polychemicals Dept., E. I. du Pont de Nemours and Co., Inc., Wilmington, Del. Affiliated with the Society for the past 25 years, Mr. Dodge had been very active in Committee D-3 on Gaseous Fuels, also represented this group on Committee E-1 on Methods of Testing.

Charles T. Evans, Jr., formerly manager, high temperature metals, has been appointed vice-president, technology and development, Universal-Cyclops Steel Corp., Bridgeville, Pa. Mr. Evans has been very active in the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals, serving on many of the panel groups, and for many years heading the Gas Turbine Panel.

Edgar W. Fasig, general superintendent, The Lowe Brothers Co., Dayton, Ohio, received the 1955 George B. Heckel Award, the highest individual award in the paint industry. The award is given annually by the Federation of Paint and Varnish Production Clubs to the individual who, in the opinion of the selection committee, has made extraordinary contributions to the industry in technology and production. A former ASTM Director, Mr. Fasig has been very active for the past 30 years in Committee D-1 on Paint Varnish, Lacquer, and Related Products, currently serving as vice-chairman of the main group, and heading the Advisory and Inter-Committee Relations Subcommittees.

The following were among 28 persons recently appointed to serve on the Publications Advisory Board of the American Chemical Society: **Arno C. Fieldner,** retired fuels technologist, U. S. Bureau of Mines; **Robert M. Fowler,** chief research chemist, Electro Metallurgical Co., Metals Research Labs.; **Wayne E. Kuhn,** general manager, Texas Co., Research and Technical Dept.; and **Villiers W. Meloche,** professor of analytical chemistry and chairman of Analytical Div., Chemistry Dept., University of Wisconsin.

Frank Garratt has retired as vice-president and technical director, Universal-Cyclops Steel Corp., Bridgeville, Pa. He will remain with the company as a director and serve as a senior consultant to management.

Roman F. Geller has retired as chief of the Porcelain and Pottery Section of the National Bureau of Standards, Washington, D. C., after 35 years of Government service. He will continue, however, on a part-time basis, to serve as chairman of the Editorial Committee of the Mineral Products Division. Active in many organizations, Mr. Geller served as first secretary of ASTM Committee C-21 on Ceramic Whiteware and Similar Products.

Milton A. Glaser, vice-president, Midland Industrial Finishes, Waukegan, Ill., is president-elect of the Federation of Paint and Varnish Production Clubs.

George E. Gronemeyer is now president and general manager, Mirror Insulation Co., Lambertville, N. J.

Russell W. Henke, formerly in charge of research and development, Badger Meter Manufacturing Co., Milwaukee, Wis., is now chief engineer, Seaman-Andwall Corp., in the same city.

Emil G. Holmberg, until recently chief metallurgist, Alloy Steel Products Co., Linden, N. J., has joined the Corrosion Engineering Section, Development and Research Div., International Nickel Co., New York City.

H. Clay Howell, formerly with Brighton Terminal, Ltd., Brighton, La Brea, Trinidad, B.W.I., is now on the technical staff of Witco Chemical Co.., Pioneer Products Div., Perth Amboy, N. J.

William S. James, until recently vice-president in charge of research and engineering, Fram Corp., Dexter, Mich., and formerly on the research staffs of the Studebaker Corp. and the Ford Motor Co., has established a consulting engineering business in Detroit. Mr. James has been very active for many years in the

(Continued on page 79)

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FOR FURTHER INFORMATION CIRCLE 105 ON READER SERVICE CARD PAGE 101

(*Continued from page 75*)

work of ASTM Committees D-2 on Petroleum Products and Lubricants, and D-11 on Rubber and Rubber-Like Materials.

Morris Katz has been named consultant in atmospheric pollution in the Department of National Health and Welfare, Ottawa, Canada.

A. B. Kinzel, vice-president of research, Union Carbide and Carbon Corp., has been elected a vice-president by United Engineering Trustees, Inc., New York City.

John D. Kleis has been appointed manager, Electrical Contact Div., Fansteel Metallurgical Corp., Chicago, Ill.

Alex Charles Knox, formerly engineer-inspector, Associated Engineering (N. Z.), Panmure, Auckland, is now metallurgist, D. P. Fisher, Ltd., Wellington, New Zealand.

Louis C. McCabe, formerly scientist director in the United States Public Health Service, recently announced formation of Resources Research, Inc., a firm of consultants specializing in solving air and stream pollution problems for industry and Federal and state governmental agencies. Mr. McCabe, who served as the first director of the Los Angeles Air Pollution Control District, will be joined in the new enterprise by **Frederick S. Mallette,** executive secretary of the Committee on Air Pollution Controls and research manager of The American Society of Mechanical Engineers, and William S. McCabe, consulting geologist of Casper, Wyo. With main office in Washington D. C., and branches in New York City and Casper, the company will handle research and development in geology, mining, industrial wastes, water resources, and the economics and supply of conventional and atomic fuels. Dr. L. C. McCabe serves as chairman of ASTM Committee D-22 on Methods of Atmospheric Sampling and Analysis, and Mr. Mallette as vice-chairman.

Milburn J. O'Neal, Jr., Analytical Research Group, Shell Oil Co., Houston, Tex., received the 1955 Precision Scientific Co. Award in Petroleum Chemistry for outstanding contributions to knowledge of the chemical composition of petroleum oils and waxes. Mr. O'Neal is chairman of ASTM Committee E-14 on Mass Spectrometry.

A. W. Pope, Jr., chief research engineer, Waukesha Motor Co., Waukesha, Wis., is serving a two-year term on the Council of the Society of Automotive Engineers.

Harry E. Rapp, formerly associated with Surface Chemicals, Inc., McKees Rocks, Pa., is now technical director, The Lubrizol Corp., Cleveland, Ohio.

Leonard Raymond, chief automotive engineer, Socony-Mobil Oil Co., Inc., New York City, is serving on the SAE Council as vice-president, fuels and lubricants.

Kenneth D. Reed, formerly manager, Mill Lubrication Dept., Industrial Div., The DeLaval Separator Co., Pittsburgh, Pa., is now manager, Lubrication Section, Dravo Corp., in the same city.

Leslie E. Simon, retired major general and former assistant chief of ordnance for research and development, U. S. Army Ordnance Corps, has been appointed director of the Research and Development Div., Carborundum Co.

R. C. Sprague, founder and chairman-of-the-board of the Sprague Electric Co., North Adams, Mass., has been named chairman of the Federal Reserve Bank of Boston and its fiscal agent.

Robert L. Terrill has been appointed production superintendent at Spencer Kellogg & Sons, Inc., Buffalo, N. Y. He will assume direction of the firm's production and central control laboratories. He had been manager of industrial products research.

(*Please turn page*)

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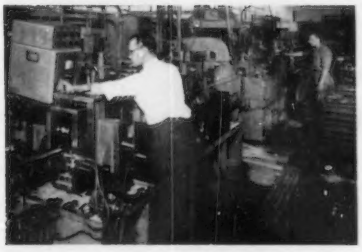

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CIRCLE 106 ON READER SERVICE CARD
PAGE 101

William R. Toeplitz has been elected president of the Bound Brook Oil-Less Bearing Co., Bound Brook, N. J. He was previously vice-president in charge of engineering. Recognized as an authority in the powder metallurgy field, Mr. Toeplitz has been active in ASTM Committee B-9 on Metal Powders and Metal Powder Products since its organization, serving as its first secretary (1944–1948).

Claude F. Waldron, previously assistant section engineer, American Bosch Div., American Bosch Arma Corp., Springfield, Mass., is now chief engineer, American Bosch Arma Mississippi Corp., Columbus, Miss.

William C. Walker has severed connection with National Printing Ink Research Inst. to join West Virginia Pulp and Paper Co., Williamsburg, Pa., as director of the new Development Laboratory.

Harold W. Washburn, vice-president and director of research, Consolidated Engineering Corp., Pasadena, Calif, received the 1955 ACS Beckman Award in Chemical Instrumentation, sponsored by Beckman Instruments, Inc. He was cited for his "internationally recognized contributions to chemical analysis by means of the mass spectrometer." Mr. Washburn is active in ASTM Committee E-14 on Mass Spectrometry.

Russell K. Wheeler, formerly with A. W. Williams Inspection Co. as Pensacola Branch Laboratory manager, is now director, Pensacola Testing Laboratories, Pensacola, Fla.

Emund M. Wise has been appointed assistant to **F. L. LaQue,** vice-president and manager, Development and Research Div., The International Nickel Co., New York City. Both Messrs. LaQue and Wise have been active in ASTM technical work for many years. Mr. LaQue who has been active also in administrative work of the Society, is currently serving a term on the Board of Directors.

Harold Wittcoff has been appointed director of chemical research, General Mills, Inc., Minneapolis, Minn. He will be responsible for the administration of the Chemical Research and Engineering Departments.

F. P. Zimmerli, director of research and engineering, Barnes-Gibson-Raymond Div., Associated Spring Corp., Plymouth, Mich., is serving a two-year term on the Council of the Society of Automotive Engineers.

DEATHS...

James W. Ames, president, W. Ames and Co., Jersey City, N. J. (September 10, 1955). Representative of company membership since 1944, serving on Committee A-1 on Steel and its Subcommittee I on Steel Rails and Accessories.

I. Chesler, director of research, Eagle Pencil Co., New York City (July 21, 1955). Representative of company membership since 1931.

C. H. Crawford, consulting engineer, Chesapeake, Lawrence Co., Ohio. Member since 1914. Representative of American Society of Mechanical Engineers since 1949 on ASA Sectional Committee B-36 on Standardization of Dimensions and Materials of Wrought-Iron and Wrought-Steel Pipe and Tubing.

Charles F. Duchacek, senior chemical engineer, Technical Service Dept., Socony Mobil Oil Co., Brooklyn, N. Y. (October 10, 1955). Member since 1941.

Valens Jones, representative, The Master Builders Co., Denver, Colo., and for many years a Bureau of Reclamation engineer noted for his work in the development of procedures and equipment for testing concrete for dams and related structures (January 2, 1956). Member since 1948.

Charles H. Lynam, refinery chief chemist, Standard Oil Co. of California, El Segundo, Calif. (November 9, 1955). Member of the Society since 1927, and very active for many years in a number of the technical committees including D-1 on Paint, Varnish, Lacquer, and Related Products; D-2 on Petroleum Products and Lubricants, and several of the Research Divisions and subcommittees; D-9 on Electrical Insulating Materials; and D-16 on Industrial Aromatic Hydrocarbons and Related Materials.

Henry R. Power, consultant, Niagara Falls, N. Y. (for many years director, Chemical Laboratory, Carborundum Co.) (December 9, 1955). Member since 1916.

Herbert Maxwell Shilstone, President, Shilstone Testing Laboratory, New Orleans, La. (Baton Rouge, La.; Houston and Corpus Christi, Tex.) (September 1, 1955). Distinguished in the consulting chemical and sanitary engineering field, Dr. Shilstone was the inventor of Carbrox, decolorizing carbon. A member of ASTM since 1922, his other organizational affiliations included the American Chemical Society, American Concrete Inst., and the Rotary Club.

Edmond L. Sweeney, superintendent, Everett Plant, Boston Consolidated Gas Co., Everett, Mass. (March, 1955). Member since 1946.

Gosta Vennerholm, manager, Manufacturing Research Dept., Ford Motor Co., Dearborn, Mich. (September 8, 1955). Representative of company on Committee A-3 on Cast Iron, and its Subcommittee XXIV on Nodular Iron since 1950. Representative of Society of Automotive Engineers on Committee A-1 on Steel from 1946 to 1952.

Alan Wood, 3d, mechanical engineer, Bryn Mawr, Pa. (December 6, 1955). Member since 1908.

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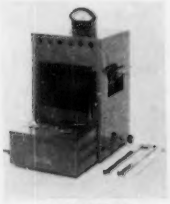

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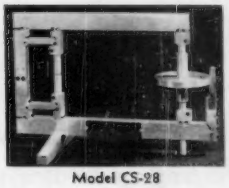

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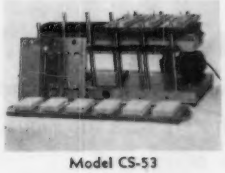

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The Automatic Alundum Guarded Hot Plate Console provides an automatic system for determining accurately the coefficients of thermal conductivity for various insulating materials. (ASTM designation C177-45)

Model 140-A

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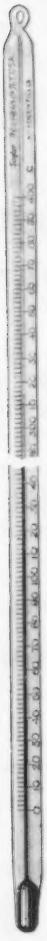

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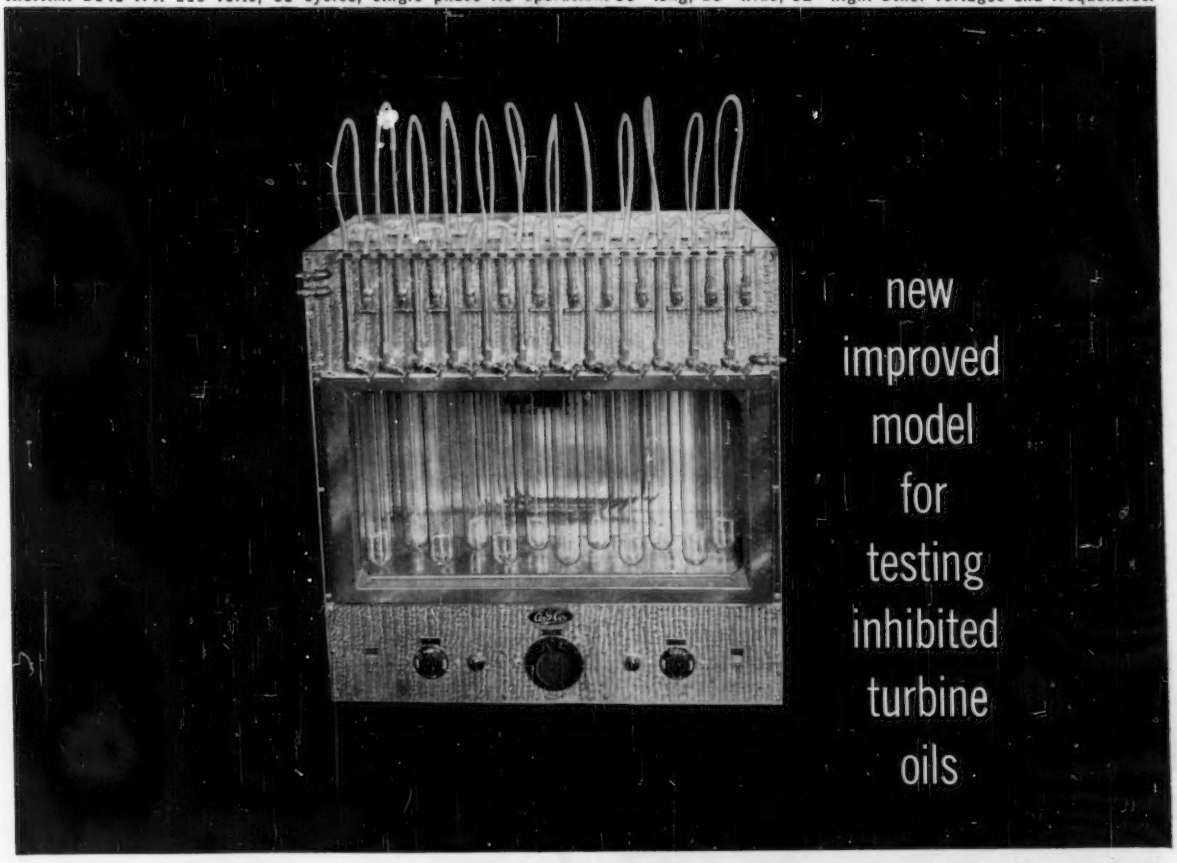

turbine oil oxidation bath

This bath determines the oxidation inhibitor life of inhibited turbine oils. The oil sample, in the presence of water, oxygen and an iron-copper catalyst, is subjected to a temperature of 95°C ± 0.2°C.

The bath accommodates 12 oxidation test cells. It is made of corrosion resistant stainless steel. It utilizes "flow-rater" type flowmeters, made of pyrex brand glass, with stainless steel floats. Individual needle flow control valves assure a rate of flow of three liters of oxygen per hour to each test cell. The water manifold has valve connections for mushroom type condensers.

The bath's window is made of tempered polished "Tuf-flex" plate glass. Two fluorescent lamps permit the operator to view the rate of oxidation and eliminate the need for removing the cells in determining sample level. A stainless steel centrifugal pump accomplishes uniform stirring without turbulence.

In conjunction with the lo-lag stainless steel heaters, a sensitive mercury-in-glass-type thermoregulator operates a mercury plunger relay on the intermittent heat circuit. Another bank of heaters quickly brings the bath up to operating temperature. An additional heater circuit permits steady continuous heat input. All control knobs are conveniently mounted on the lower front panel for ease of operation.

PRICE LIST

G18765	Steam Turbine Oil Oxygen Bath, 12 unit improved model, complete as described above but without oil test cells (which consist of test tube, mushroom condenser and oxygen delivery tube).	each	$1,750.00
G18772	Oil Tube Pyrex brand glass	each	3.75
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G18776	Oxygen delivery tube	each	4.50
G18778	Copper wire catalyst per 1000 ft		11.50
G18780	Iron wire catalyst per 1000 ft		6.00
G18782	Winding fixture for wire catalyst	each	150.00

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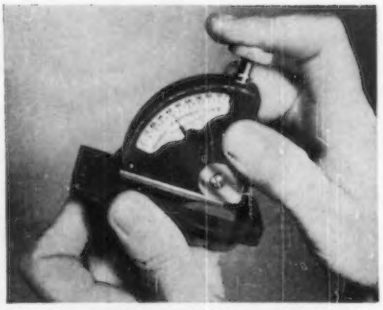

The Shore Durometer is available in various models for testing the entire range of rubber hardness.

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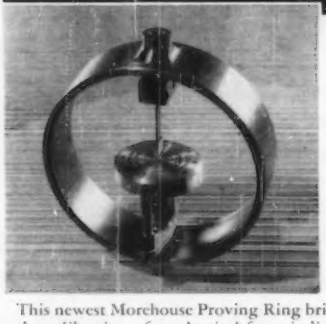

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Kodak reports to laboratories on:

some information we hope you'll use and some we hope you won't . . . how to bring somebody else's slide lecture back home . . . looking through the microscope with movie film and camera

Data for the times

As a kind of a public service, we feel we ought to print the following table:

KODAK FILM	Kodak Developer	Time (min.)	1,000-KVP X-rays—Roentgens for density of		
			0.3 net	1.0 gross	2.0 gross
1. Kodak Royal Pan Film	DK-60a	4	1.2	13.2	440
2. Eastman Plus-X Panchromatic Negative Film	D-76	8	3.7	19	450
3. Kodak Commercial Film	DK-50	5	4.3	47	305
4. Kodak Contrast Process Panchromatic Film	D-11	5	11.5	36	98
5. Kodak Infrared Aerographic Film	D-19	9.6	1.2	4.0	18
6. Kodak Linagraph Ortho Film	D-19	7	1.1	3.2	12
7. Kodak Super-XX Aerographic Film	D-19	9.6	1.2	3.8	17
8. Kodalith Ortho Film, Type 2	Kodalith	2.25	—	1400	1700
9. Recordak Micro-File Panchromatic Film	Kodagraph	5	90	220	560

We have three reasons for printing it, in decreasing order of importance.

1) In the event of nuclear disaster, pieces of film that survive lighttight might serve as fortuitous dosimeters. Few American population centers of 10,000 souls or more wouldn't contain at least a box or two of such a popular product as *Kodak Royal Pan Film.* Giving it the above-indicated processing normally recommended for that film would provide a radiological survey party with a quick and rough estimate of the amount of prompt radiation that hit where the film was stored. The table neglects the possibility of solarization, but perhaps this is an excessively lugubrious thought.

2) In these nuclear times, the question often arises of how much radiation it takes to spoil film for its intended purpose. Here is a guide to tolerance judgments, since the sensitivity of a particular photographic material is essentially the same for all radiations harder than 1,000-kvp x-rays.

3) It's an excuse to tick off a few film names you might like to know about. No. 2 is one of the main threads for Hollywood's loom of glamour and glory. No. 3 is sheet film with good tone rendition for monochrome subjects, slow enough for processing by inspection under a relatively bright Series 1 Safelight. No. 4 is the basic sheet film for black-and-white photomicrography. No. 5 has sensitivity out to nearly 10,000Å and comes in widths up to 9½" and lengths up to 390 feet. No. 6 is 16mm and 35mm film for recording repetitive patterns from green-emitting c-r tubes, unaffected by reddish cathode glow. No. 7 is the world's No. 1 film for aerial photography. No. 8 is a sheet film that gives either inky blackness or diaphanous clarity and nothing much between. And No. 9 provides 16mm or 35mm sanctuary for records by the billions.

For more detailed information on the radiation sensitivity of more Kodak films, write Eastman Kodak Company, X-ray Division, Rochester 4, N. Y., who hope that the only film ever given an opportunity to soak up roentgens will be Kodak X-ray Film.

Convention trophies

Bumped into a lad the other day who is director of photo services at one of the big Middle Western universities. It was at a meeting of a technical society, and he had spied us in the act of outwitting a speaker who was impressing the audience by zipping slide after slide of big, fat tables of numerical data onto the screen. There we sat in the dark with a little camera, popping away at each slide so that when we got home we could take our own sweet time deciding just how impressed to be.

We thought we would have a chance to expound to the fellow a little on film, aperture, and shutter speed involved in this photographic feat, but it turned out this type of cagey operation is straight routine with him and we couldn't tell him a thing he didn't know already. One of the regular duties of his office is to supply staff members with cameras to catch the slides at meetings.

With any luck and a steady hand, a camera no more elaborate than the Kodak Pony 135, Model C, *which comes with an f/3.5 lens for $33.75, should pick up readable copies of slides on* Kodak Tri-X Film *when shot wide open at 1/25 sec. from a point in the room where the screen image just fills the finder. It could provide something more definite to bring home from a meeting than a feeling of solidarity with one's discipline.* (*Caution: copying a man's slides without his permission could conceivably earn one a punch in the nose.*)

Cinephotomicrography

That motion pictures made through the microscope might have much value both as an investigative technique and as an aid to scientific communication and instruction doubtless occurred to thoughtful men in earliest nickelodeon days, if not before. Certainly the art has been widely and effectively practiced and improved since then, but how many laborers in the various vineyards have had too many other important and more difficult matters meriting their attention to give thought to what cinephotomicrography could do for them?

Therefore, with no loftier motive than moving a little merchandise, it may be that by publishing a new revision of the booklet, "Motion Pictures Through the Microscope," we shall accomplish the greater good of a seed dropped in the right place at the right time.

The booklet speaks of how to use a motion-picture camera to alter the apparent rate of events on a microscope stage, making them many thousandfold faster or four times slower, as desired; of the details of aligning camera with microscope; of illumination, exposure, color rendition, the defeat of vibration, and a hundred other petty points that distinguish exasperation from proud achievement.

A copy of "Motion Pictures Through the Microscope" (Kodak Pamphlet N-2) is obtainable without charge from Eastman Kodak Company, Sales Service Division, Rochester 4, N. Y.

Price includes Federal Tax and is subject to change without notice.

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

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FOR FURTHER INFORMATION CIRCLE 116 ON READER SERVICE CARD PAGE 101

NEW MEMBERS . . .

The following 149 members were elected from January 1, to January 17, 1956, making the total membership 8165 . . . . . Welcome to ASTM

Note—Names are arranged alphabetically—company members first then individuals.—Your ASTM Year Book shows the areas covered by the respective Districts.

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Multer, Robert K., development engineer, Marbon Chemical Division, Borg-Warner Corp., 1926 W. 10th Ave., Gary, Ind. [A]*

Pereles, Richard A., assistant director of Research, Pereles Brothers, Inc., 2484 S. 7th St., Milwaukee 15, Wis. [A]

Rogalski, Leonore, library supervisor, Universal Oil Products Co., 30 Algonquin Rd., Des Plaines, Ill.

Sorrentino, Francis C., chief experimental engineer, National Presto Industries, Inc., Eau Claire, Wis.

Vitovec, Franz H., associate professor, Experimental Engineering Station, University of Minnesota, Minneapolis 14, Minn.

Weber, R. Frank, packaging editor, *Modern Materials Handling*, Boston, Mass. For mail: 2365 N. 73rd St., Milwaukee 13, Wis

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Cleveland, Allen E., chief development engineer, Development Dept., Ford Motor Co., Engineering Staff, Box 2053, Dearborn, Mich.

FitzSimons, Neal, civil engineer, Engineering Dept., Kellogg Co., Battle Creek, Mich. For mail: R.R. #7, Box 59-A, Battle Creek, Mich. [A]

Florance, Warren A., research chemist, General Motors Corp., Research Staff, Box 188, North End Station, Detroit 2, Mich.

Leithauser, Gene L., research chemist, General Motors Corp., Research Staff, Box 188, North End Station, Detroit 2, Mich. [A]

Ottolini, Albert C., research chemist, General Motors Corp., Research Staff, Box 188, North End Station, Detroit 2, Mich. [A]

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Brodrick, Ronald F., project engineer, Lessells and Associates, Inc., 916 Commonwealth Ave., Boston 15, Mass. For mail: 64 S. Elm St., West Bridgewater, Mass.

Chapin, John W., mechanical engineer, Textile Engineering Lab., Textile, Clothing and Footwear Div., Quartermaster Research and Development Command, U. S. Department of the Army, Lowell, Mass. For mail: 290 Pine St., Lowell, Mass. [A]

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Dalton, Thomas F., chemist, Magnus Chemical Co., South Ave., Garwood, N. J. [A]

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(Continued on page 88)

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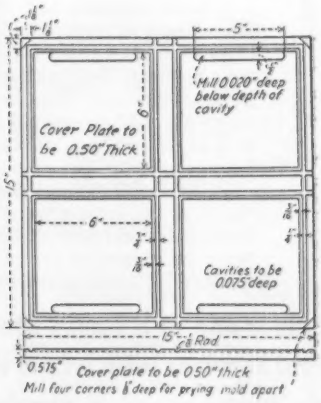
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Weight—*only* 37 lbs.
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Working chamber:
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Includes vacuum gauge, 1 shelf, 2 valves, thermometer, neon pilot light, cord and plug. Order now for quick delivery.

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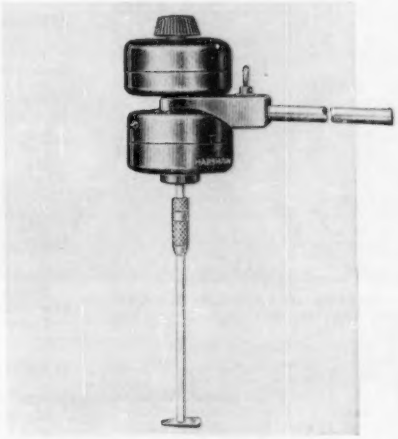

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Wawrousek, Robert, assistant metallurgist, Parish Pressed Steel Co., Division of Cana Corp., Robeson and Weiser Sts., Reading, Pa.

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Crum, Ralph G., Civil Engineering, Carnegie Institute of Technology, Box 377, Pittsburgh, Pa. [A]

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Lever, Harry R., general manager, Power Engineering and Equipment Co., Inc., 1826 W. 213th St., Torrance, Calif.

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Edwards, J. B., Box 13226, Dallas 20, Tex.

William, T. C., vice-president, The Renery Supply Co., 621 E. 4th St., Tulsa 20, Okla.

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Braaten, Everett O., chief product design engineer, PSC Applied Research, Ltd., 1500 O'Connor Dr., Toronto, Ont., Canada.

Dunlop, John Herbert, executive engineer, Dominion Gasket and Manufacturing Co., Ltd., 2 Scarlett Rd., Toronto 9, Ont., Canada.

Kall, Harold L., laboratory manager, Carborundum Metals Co., Box 32, Akron, N. Y.

Morgan, Robert W., vice-president of engineering, Rochester Manufacturing Co., Inc., 100 Rockwood St., Rochester 10, N. Y.

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Beach, Lamar, Technical Sales, The Chemstrand Corp., Decatur, Ala.

Carpenter, Robert L., chemist, Empire State Oil Co., Box 334, Thermopolis, Wyo. [A]

Chan, Clarence K., civil engineer, research assistant, Post Engineers, Ft. Huachuca, Ariz. For mail: 1016 E. Helen St., Tucson, Ariz. [A]

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Harris, Lewis E., director, Harris Laboratories, 816 P St., Lincoln 1, Nebr.

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Smith, Thomas L., mechanical engineer, Monsanto Chemical Co., Monsanto, Tenn. [A]

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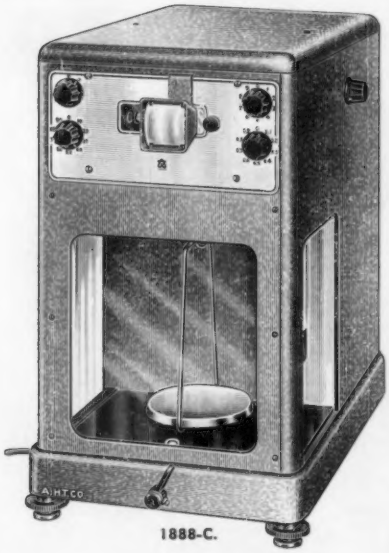

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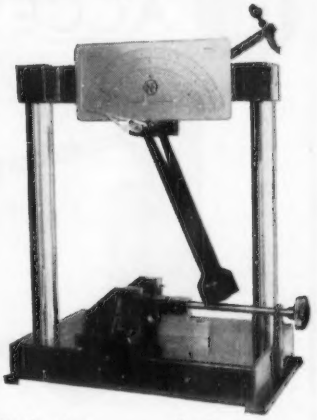

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SPECIFICATIONS

Maximum Count:
Four digits — 9,999
Maximum counting rate:
300,000 counts per minute
Input Sensitivity and Waveform:
Not critical
Outputs:
Relay contact 10 Amperes
Pulse output 50 volts
Size:
8 x 6 x 12 inches
Weight:
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Power:
25 watts
105-125 volts, 50-60 cycles
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- Motor-driven Flow Table
- Wagner Turbidimeter (ASTM C115)
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Strain Gages—New SR-4 resistance-type strain gages for use at temperatures up to 1800 F. *Baldwin-Lima-Hamilton Corp.* 1002

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Polisher—Selecto-Speed polishers having infinitely variable speed between 100 and 1200 rpm. *Buehler Ltd.* 1004

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Testing Machines Explained—Universal testing machines are presented in a new 12-page *Bulletin 4401*. Hydraulic machines with capacities from 10,000 to 5,000,000 lb are described, including standard and special types of vertical and horizontal machines. *Baldwin-Lima-Hamilton Corp.* 2001

Beckman Bulletin—An "Electronic hot-rod that accelerates ions 1000 miles per second in a millionth of a second," automatic spectrophotometers which speed laboratory analysis and a new pH electrode are all described in *Bulletin No. 17. Beckman Div., Beckman Instruments, Inc.* 2002

Lead Sulfide Photoelectric Cell—Booklet on the *Kodak Ektron Detector*, a unique type of photoelectric cell which utilizes the peculiar electric properties of lead sulfide, and which is characterized by its small size, mechanical ruggedness, and high sensitivity to radiation in the infrared, visible, and ultraviolet portions of the spectrum. *Eastman Kodak Co.* 2003

Laboratory Emergency Chart—The unique *A-to-Z* (acetone to zinc) as treatments for specific poisons (as well as treatments for particular accidents and for corrosive chemical burns) has made the chart a standard item in laboratories throughout the world. *Fisher Scientific Co.* 2004

Fluorimeter—December issue of JAco News Letter. *Jarrell Ash Co.* 2005

Tracing Templates—Portfolio containing forty-eight 8½ by 11 in. tracing templates for time and money saving tracings of strap clamp assemblies, hand knobs, speed handles, etc. *Jergens Tool Specialty Co.* 2006

Combustion Unit—*Bulletin LEP-1* describing a high frequency combustion unit for rapid determination of total sulfur in diesel fuel, kerosene, oil sludges, lubricating oils, lubricating oil additives, tars, asphalts, spent caustics, and other inorganic materials. *Laboratory Equipment Div., Lindberg Engineering Co.* 2007

Proportional Counter Converter—*Bulletin PCC-14* gives full details on the first self-powered proportional counter converter to be available on a commercial basis. *Nuclear Measurements Corp.* 2008

The Nucleus—*The Nucleus* describes new Isotope Scanner. This unit, used with a directional scintillation detector and scaler, provides a means of scanning body areas for concentrations of radioactive isotopes while simultaneously drawing a "picture" of the isotope distribution. *Nuclear Instrument and Chemical Corp.* 2009

Oxygen Combustion Bombs—Seven different bombs for calorimetry and oxygen combustion tests are described in a new 16-page illustrated bulletin. *Parr Instrument Co., Inc.* 2010

Laboratory Equipment—Catalog featuring steel shelving and lockers as well as other storage and maintenance equipment for industrial and institution use. *Precision Equipment Co.* 2011

Chromatographic Analysis—*Data Sheet No. 11193* on the redesigned Chromatopile, a simple but versatile apparatus for physi-

(*Continued on page 95*)

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(*Continued from page 92*)

cal separations of solutions and chromatographic analysis with filter paper. *Precision Scientific Co.* 2012

Distillation Apparatus—*Bulletin 716* on front-view distillation units for petroleum products. *Precision Scientific Co.* 2013

Dial Thermometer—New bimetallic dial thermometer for a wide variety of applications (*Bulletin No. 98267*). *Taylor Instrument Co.* 2014

INSTRUMENT COMPANY NEWS

Baird Associates, Inc., Cambridge 38, Mass.—Bruce H. Billings, director of research at Baird Associates, Inc., Cambridge, has been named general manager.

Freed Transformer Co., Inc., Brooklyn, N. Y.—The emphasis on industrial applications of electronic equipment for control and automation in the textile, metallurgical, oil refining, and electromechanical fields has resulted in a 100 per cent increase in the staff since the war.

NEWS OF LABORATORIES

Truesdail Laboratories, Inc., Los Angeles, Calif.—Truesdail Laboratories, Inc., of Los Angeles, prominent research and testing firm, has established an operation division laboratory in Honolulu, and arrangements have been made to lease space in a new building soon to be erected by Hawaii Chemical Co., Ltd.

St. John X-Ray Laboratory, Califon, N. J.—Herbert R. Isenberger, president, has recently been appointed member of the Governor's (N. J.) Advisory Committee on Radiation Protection.

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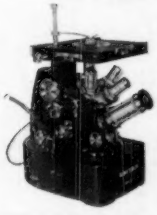

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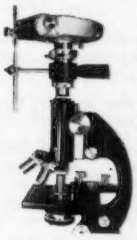

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OTHER SOCIETIES' EVENTS

February 27–March 2—**Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy,** Exposition of Modern Laboratory Equipment, Wm. Penn Hotel, Pittsburgh, Pa.

March 1–2—**Forest Products Research Society,** Royal York Hotel, Toronto, Ont., Canada.

March 6—**Society for Applied Spectroscopy,** Hotel New Yorker, New York, N. Y.

March 6–10—**American Concrete Pipe Assn.,** Annual Meeting, Broadmoor Hotel, Colorado Springs, Colo.

March 8–9—**Society of Plastics Industry,** 14th Annual SPI Canadian Conference, Sheraton-Brock Hotel, Niagara Falls, Ont., Canada.

March 12–16—**National Association of Corrosion Engineers,** Show, Hotel Statler, New York, N. Y.

March 18–21—**American Society of Mechanical Engineers,** Spring Meeting, Multonomah Hotel, Portland, Ore.

March 19–20—**Steel Founders Society,** Annual Meeting, Drake Hotel, Chicago, Ill.

March 19–23—**American Society of Tool Engineers,** 24th Annual Convention, International Amphitheatre, Chicago, Ill.

March 20—**Society for Applied Spectroscopy,** Philadelphia College of Pharmacy & Science, Philadelphia, Pa.

March 21–24—**National Institute of Radio Engineers,** Convention and Exhibit, Belmont Plaza, New York, N. Y.

March 27–April 2—**Society of Plastics Industry,** 13th Annual Pacific Coast Section Conf., St. Francis Hotel, San Francisco, Calif., and S.S. *Lurline* to Honolulu.

April 8–13—**American Chemical Society,** Spring Meeting, Dallas, Tex.

April 10–12—**Metal Powder Assn.,** 12th Annual Meeting and Metal Powder Show, Hotel Cleveland, Cleveland, Ohio.

April 12–13—**Malleable Founders' Society,** 7th Market Development Conference, Edgewater Beach Hotel, Chicago, Ill.

April 23–25—**American Oil Chemists' Society,** 47th Annual Spring Meeting, Shamrock Hotel, Houston, Tex.

April 23–25—**Electron Physics International Conference,** College Park, Md.

April 26–27—**American Institute of Electrical Engineers,** National Meeting, Bradford Hotel, Boston, Mass.

April 29–May 1—**The Electrochemical Society,** Mark Hopkins Hotel, San Francisco, Calif.

April 29–May 4—**Society of Motion Picture and Television Engineers,** Hotel Statler, New York, N. Y.

May 3—**Non-Ferrous Founders' Society,** Annual Membership Meeting, Atlantic City, N. J.

May 4—**American Association of Spectrographers,** 7th Annual Conference, Chicago, Ill.

May 3–9—**American Foundrymen's Soc.,** Annual Convention, Atlantic City, N. J.

May 6–9—**American Institute of Chemical Engineers,** Roosevelt Hotel, New Orleans, La.

May 8–11—**ASME Metals Engineering—AWS Conference,** Hotel Statler, Buffalo, N. Y.

May 23–25—**ASME-EIC Meeting,** Mount Royal Hotel, Montreal, Que., Canada

May 22–24—**Association of American Railroads,** Netherland Plaza, Cincinnati, Ohio

June 3–8—**SAE Annual Meeting,** Chalfont-Haddon Hall, Atlantic City, N. J.

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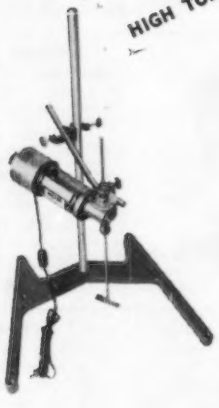

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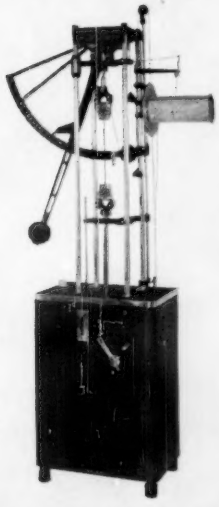

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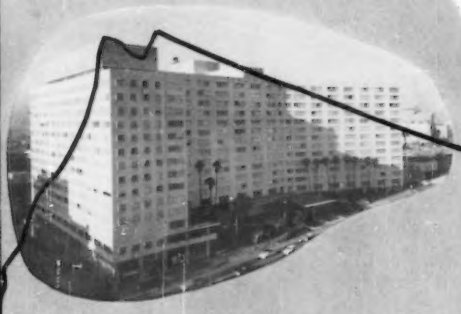
Two ASTM Exhibits in 1956

12th EXHIBIT OF TESTING AND SCIENTIFIC APPARATUS AND LABORATORY SUPPLIES

Held in conjunction with the 59th Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J., June 18-22, 1956



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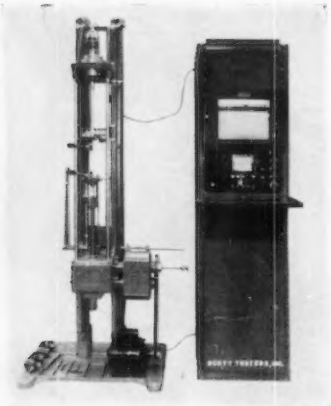

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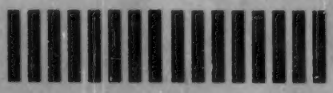

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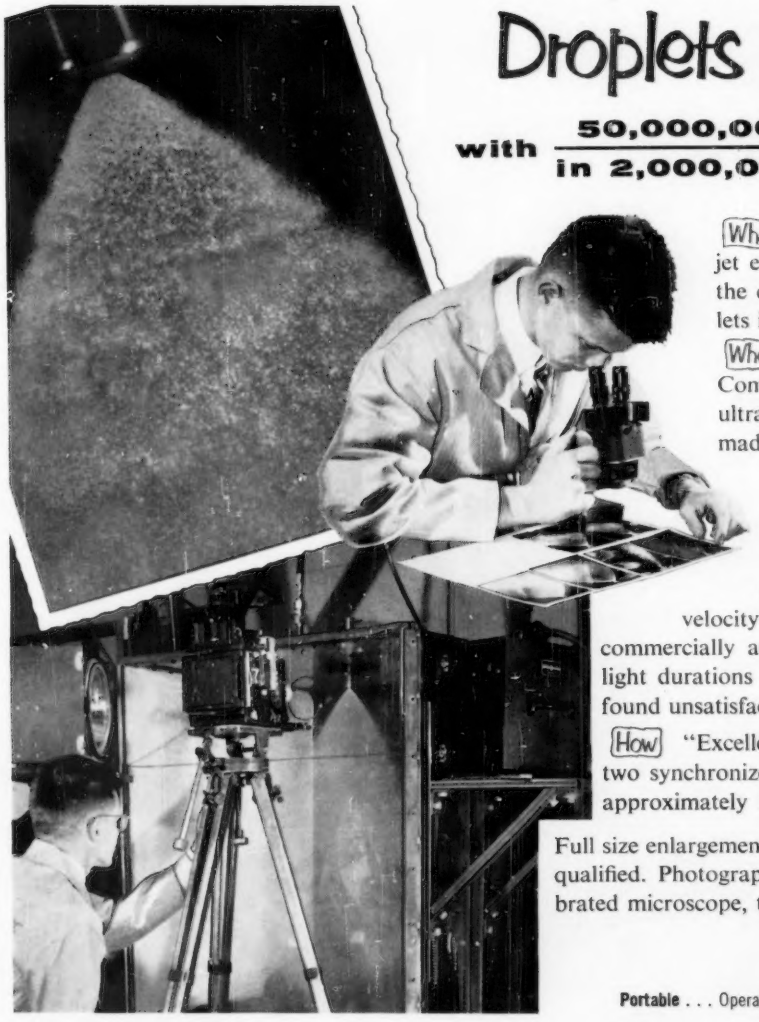

What Fuel nozzles for high-performance jet engines must be carefully designed for the desired range and magnitude of droplets in the fuel spray.

Who and Why The Parker Appliance Company, Cleveland, Ohio, has found ultra-high-speed photographic techniques made possible by the G-R Microflash most satisfactory for this work. To quote Ned Shiflet, Manager of the Engine Accessories Division: "Flash bulbs of 1/80 second to 1/170 second light duration would not stop the high-velocity droplets in the atomized fuel spray. A commercially available high-speed electric flash with light durations as small as 1/30,000 second was also found unsatisfactory."

How "Excellent photographs are now obtained using two synchronized Microflash units. These are located approximately 15 inches from the spray cone at 90°. Full size enlargements can easily be made and droplet sizes qualified. Photographs obtained are studied under a calibrated microscope, to determine actual droplet sizes."

G-R Type 1530-A

Microflash®

$640.00

This instrument will "stop" objects moving as fast as 1,000 feet per second. It makes possible detailed study and analysis of projectiles in motion, pressure waves in gases, turbulence in liquids, and mechanical distortions.

Flash Duration — 2 microseconds

Triggering — Pushbutton initiates flash — flash can also be triggered by sound or pressure wave produced by the action to be photographed; microphone and built-in amplifier are provided for this use.

Mounting — Power Supply and trigger circuits are in one metal case, the flash lamp in another. Both cases lock together for ease in transportation, and complete protection of lamp and controls.

Dimensions — 24¼ x 13¼ x 11¾ inches. **Net Weight** — 72 pounds.

Portable . . . Operates from ordinary 115/220v a-c lines . . . can be used with conventional camera equipment.

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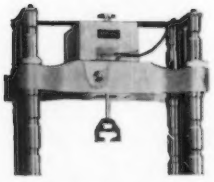
	R-L-C STANDARDS	WAVE FILTERS

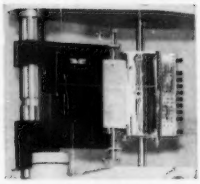
FOR FURTHER INFORMATION CIRCLE 134 ON READER SERVICE CARD PAGE 101

Here's Proof of the Unmatched Testing Versatility At Your Command . . . . . with an OLSEN

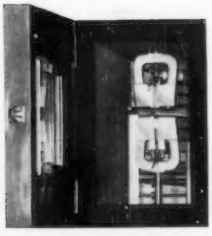


With a LOAD CELL, ranges as low as 0 to 5 lbs. represent full dial scale on even the largest Olsen.

12,000 lb. cap. Electromatic U.T.M.



HIGH TEMPERATURE FURNACE for testing at up to 2,000°F.



COLD AND HOT TESTING in a single cabinet from −75° to 600°F.

STRAIN RATE INDICATOR enables operator to adjust testing speed in terms of actual specimen strain (in./in./min.).

AUTOMATIC PROGRAM CONTROLLER for accurately conducting production, proof or various cycling tests to preset controls.

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- Over 30 different EXTENSOMETERS available for measuring strain in conjunction with a Model 51 recorder.
- Complete selection of GRIPS for every type of specimen.
- TRANSVERSE TOOLS for use with any universal or compression testing machine.
- ELECTRONIC RECORDER for producing accurate stress strain curves with magnifications from 1:1 to 1,000:1. Available with Y-axis for plotting two coordinates simultaneously.

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